CODE CHANGE PROPOSAL

2005 Title 24 Building Energy Efficiency Standards Update

Time Dependent Valuation (TDV) – Economics Methodology

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Overview

Past development and revisions of the Title 24 Energy Standards were based on electricity and natural gas costs that did not account for seasonal or time-of-use patterns (flat valuation of savings). These energy costs were based upon the annual average price of electricity ($/kWh) or natural gas ($/therm) paid by residential or commercial consumers throughout the state. However, both the price Californians pay for energy and the cost of delivering energy depends upon when and where the energy is needed. This proposal recommends using a more accurate energy costing analysis for the Standards, called Time Dependent Valuation of savings (TDV), which accounts for variations in cost related to time of day, seasons, geography and fuel type

The use of TDV criteria in the Standards to place a higher value on energy savings during the high cost times of the day and year, and which are more closely tied to the actual variations in energy costs, would encourage the design and construction of buildings which reduce the peak demands on the energy system in California. Over time, this would lead to significant cost savings for both building owners and for the utility system at large, along with improved reliability for utilities, customers and society at large.

Description

The heart of the TDV economics proposal is a methodology for deriving hourly valuations for electricity, natural gas and propane. Each set of values represents one class of buildings (residential, nonresidential), one of the three fuels, and one of the sixteen California climates. . The geographical and temporal variability in delivered energy costs are due primarily to differences in commodity prices (electricity prices are higher in summer than winter, natural gas and propane prices are higher in the winter than summer). The methodology for electricity valuation includes generation, transmission, distribution, and a revenue neutrality adjustment. The resulting hourly valuations reward energy efficiency depending on when the energy is saved, with greater valuations during on-peak conditions and lesser valuations off-peak. In addition, the TDV method is based on long range forecasts of the total costs of electricity, natural gas and propane, so it provides for more realistic comparisons of the costs and savings associated with each energy source.

Benefits

The primary benefit of the TDV methodology is to give Title 24 a more accurate way to credit the value of energy savings than it currently does with its traditional flat valuation scheme. Buildings designed under TDV will be more economical for building owners, because they will consume less energy during peak conditions. As the effects of TDV-designed buildings spread across the state, there will be a reduction in electricity system peak demands, which will save Californians the cost of new power plants and distribution systems, and will help to make the electric system more reliable. Adoption of TDV by the State of California is an effective, long-term response to the energy crisis and the threat of blackout.

Environmental Impact

There are no direct environmental impacts associated with the adoption of TDV. Over the long run, there are likely to be general environmental benefits from the reduced need for peaking plants.

Type of Change

The adoption of TDV economics by the CEC would modify the calculation procedures used in making performance calculations. This change would not add a compliance option or a new requirement, but would affect the way that tradeoffs are made. TDV values would be incorporated into the ACMs (alternative calculation methods approved for use as compliance tools), and would be used internally by the computer programs in calculating the compliance margin for a given building design. This process would be transparent to the end user, to whom the inputs and outputs of the ACM would be substantially the same as under the current standards.

TDV economics would also be used for calculating the cost effectiveness of new measure proposed for adoption into Title 24. It is not contemplated that the existing standards and their cost effectiveness would be re-evaluated under TDV; the measures currently in place within Title 24 would remain as a given. Over time, new measures, which perform better under TDV, might displace older measures which do not perform as well during peak periods.

Adoption of TDV would require changes to the ACM manuals, so that the compliance tools can correctly implement TDV. Concurrent changes made to the Title 24 engineering calculations to better implement TDV might require some adjustments to the simulation inputs to better account for measure performance (e.g. a more detailed HVAC equipment model might require more detailed inputs).

Technology Measures

Time Dependent Valuation is not a technology measure

Performance Verification

Time Dependent Valuation does not require performance verification.

Cost Effectiveness

TDV does not, in itself, need to pass any cost effectiveness tests. Rather, it provides an economics methodology for performing a new kind of cost effectiveness analysis on proposed measures.

Analysis Tools

Implementation of TDV will entail adding a new step to the calculation of energy savings in a measure. The hourly energy savings values are each multiplied by an hourly TDV factor. The results for each hour are summed over the entire 8760 hourly savings valuations for the analysis year. The TDV factors are different, depending on which of the three energy sources (electricity, natural gas, propane), which climate zone and which class (residential, nonresidential) is in question. The calculations, however, would be done internally and automatically within the compliance tools (e.g. MICROPAS, EnergyPro).

Relationship to Other Measures

The TDV economics methodology can be adopted on a stand-alone basis and applied as a new valuation methodology to the current Title 24 implementation. However, in order to realize the full benefits of TDV, we recommend that there be a number of upgrades to the engineering analyses associated with performance trade-offs and compliance. All of these engineering enhancements provide for better hourly analysis of savings, and hence more accurate treatment of those savings under TDV.

The most obvious example of a TDV engineering enhancement that should be made is in the modeling of residential HVAC systems performance. Under the current residential ACM models, the annual cooling load is calculated using an hourly loads analysis in MICROPAS. The total annual load is then simply divided by the SEER to get the annual cooling energy. If TDV is adopted, this calculation should be changed to incorporate an hourly HVAC equipment model, so that the cooling energy use is calculated for each hour. The TDV hourly factors can then be applied to these hourly energy numbers. In addition to the improved accuracy of this calculation, it would also allow Title 24 to distinguish between air conditioners which perform well under high temperatures from units which do not. Residential Title 24 could then be used to encourage or give credit for the better performing equipment.

TDV would still work without a residential HVAC equipment model, but the value of improved air conditioning would not treated as accurately. Residential envelope measures, which are already modeled on an hourly basis, would be relatively more sensitive to performance trade-offs.

There several additional TDV engineering enhancements that we will be recommending for adoption alongside this TDV economics proposal. Most of these are still in the final stages of development as of this writing, but they are expected to be completed in time for adoption under the current standards proceeding. There will be a separate CASE report prepared to explain and justify each TDV engineering enhancement. A brief description of these follows:

Residential Hourly HVAC Model

One of the fundamental engineering analysis improvements that should accompany adoption of TDV is the adoption of an hourly residential equipment model. This will enable Title 24 performance tradeoffs to more accurately reflect the performance of equipment measures relative to envelope measures.

The hourly residential HVAC and duct models have been developed to fit into the California performance path compliance calculation context with all of the limitations that implies. The need to default a large part of the information is a fundamental limit on the model. Compliance calculations are typically carried out by the energy consultant early in the process before HVAC equipment has been selected, sized and installed by the mechanical contractor. The detailed characteristics of the HVAC system are often not readily apparent in the field and not normally verified by the building inspector. Third party verification offers options for future improvements in these areas but initially, the model must work with little or no additional inputs.

Air conditioning has the largest peak demand impact of any end use in new homes so it is the highest priority for enhanced hourly simulation. The Seasonal Energy Efficiency Ratio (SEER) is the efficiency descriptor known for all residential air conditioners and is the only required input for the hourly model. SEER is derived from a laboratory test of efficiency while cycling to meet load at an outdoor temperature of 82°F. The proposed hourly model adjusts SEER (and EER if input) to remove fan energy, account for charge and airflow conditions, and for an assumed 62°F indoor wet bulb temperature. The hourly model uses the SEER to represent the compressor efficiency at 82°F and below outdoors. At 95°F the model uses the Energy Efficiency Ratio (EER) to characterize the compressor efficiency. If EER is not specified and verified as part of the compliance process, the model defaults to a conservative assumption for EER (established by the CEC during the 2001 Standards development) based on the SEER input. The compressor efficiency between 82°F and 95°F is interpolated between the SEER and EER points. Above 95°F the efficiency of the compressor is assumed to decline according to the tested impact of outdoor temperature on the efficiency of typical compressors. The efficiency versus outdoor temperature model is shown in the figure below.

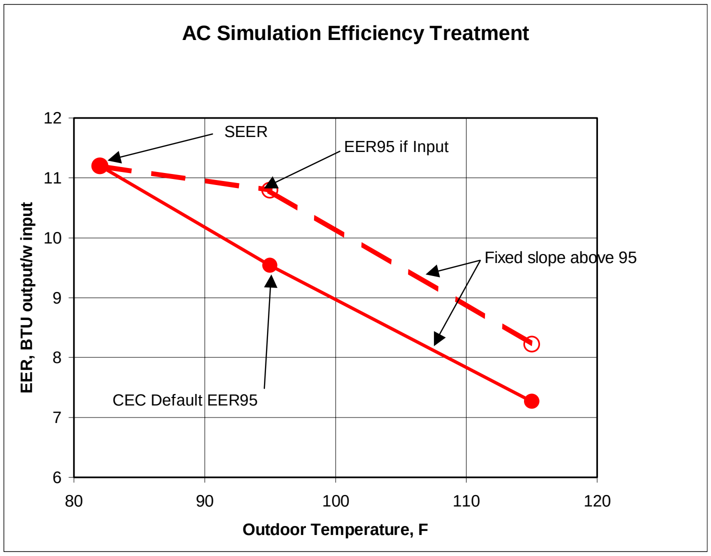

Figure 1 – Proposed Residential A/C Simulation Efficiency Treatment

CEC compliance calculations have traditionally assumed that all loads are met and this model continues that approach by assuming that cooling loads are met during the hour they occur. The compressor efficiency is adjusted to remove fan energy at the standard test value 365 W/1000 CFM and 400 CFM per ton. Fan energy is accounted for separately in the model. If fan characteristics are not input and verified, default fan characteristics of 510 W/1000 CFM and 300 CFM/ton are assumed.

Gas fired heating systems predominate in California homes and their performance does not impact electrical demand or vary significantly with outdoor conditions so they continue to be modeled using seasonal descriptors.

Heat pumps, which have a small market share in new homes, do require improved hourly modeling to account for the impact of temperature and capacity on efficiency and peak loads. The Heating Season Performance Factor (HSPF) is the descriptor that is known for all heat pumps and is the only required input. The coefficient of performance (COP) and capacity at 47°F outdoors are the primary variables in the model. If the COP47 is not input and verified during compliance, it is defaulted from the COP based on CEC data for heat pumps shown in the graph below as:

$$COP47 = 0.4 \times HSPF$$

The heating capacity of the heat pump, if not input and verified, is defaulted to the design cooling load calculated by the ACM. The DOE21E heat pump model has been adapted for use in the residential compliance programs to calculate the hourly capacity and efficiency of the compressor in relation to outdoor temperature. Heating loads not met by the compressor are assumed to be met during the hour by backup resistance heat.

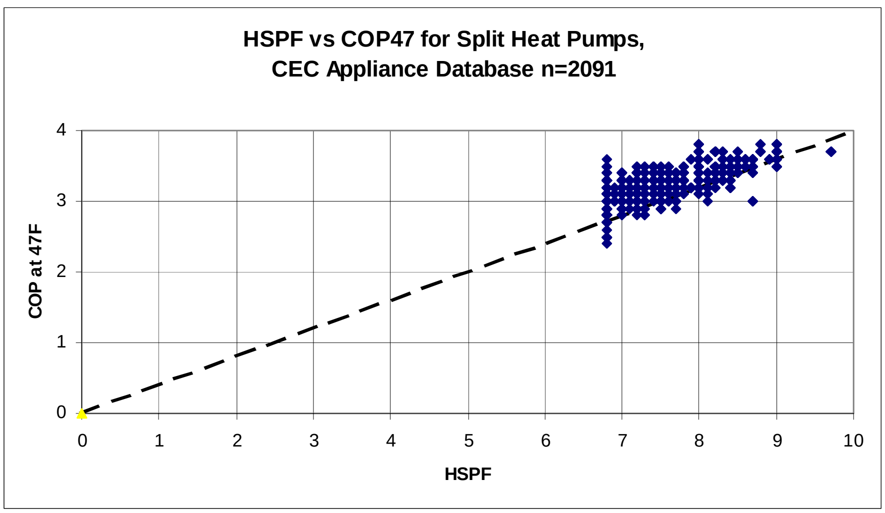

Figure 2 - HSPF vs. COP 47 for Split Heat Pumps

Residential Hourly Duct/Attic Model

Adoption of the TDV approach into Title 24 should also be accompanied by adoption of an hourly duct/attic model, so that the performance of these measures can better reflect the hourly TDV energy factors. The current approach is based on an annual estimate of duct/attic performance.

The residential ACM manual has an extensive system for calculating seasonal duct efficiency based on the approach in ASHRAE Standard 152P and these efficiencies have been required to be used in compliance calculations for some time. However, duct systems in attics have a significant variation in efficiency over time due to the variation of temperatures in the attic. This has a large impact on the on performance of residential air conditioning systems, particularly during peak periods of high outdoor temperature combined with bright sunshine. Duct system efficiency variation is also an important variable in the hourly performance of heat pump systems. The proposed residential hourly duct/attic model provides a calculation approach that accounts for these peak effects using the current compliance inputs and seasonal efficiency calculations.

Detailed simulations of a prototype house were performed using the FSEC 3.0 software tool in a several climate zones, representing the range of cooling climates experienced in California. The detailed simulation results were used to develop a regression-based model of the hourly normalized distribution efficiency using the following form to account for hourly variations in distribution system efficiency:

$$\frac{DE_{season}}{DE_{hr}} = 1 + C_{DT} \cdot \left(\frac{\Delta T_{sol,hr}}{\Delta T_{sol,season}} - 1 \right)$$

Where:

$$\Delta T_{sol} = T_{solair} - T_{in}$$

$$T_{solair} = T_{amb} + \left(\frac{\alpha}{h_o} \right) I_{hor} - \Delta T_{sky}$$

DEhr	*distribution system efficiency this hour*
DE_{season}	*seasonal average distribution system efficiency (from Current ACM Manual)*
T_{solair}	*sol-air temperature, °C*
T_{amb}	*outdoor air dry-bulb temperature, °C*
ΔT_{sky}	*reduction of sol-air temperature due to sky radiation, = 3.6°C*
I_{hor}	*global solar radiation on horizontal surface, kJ/hr m2*
α	*solar absorptivity of roof = 0.50*
h_o	*outside surface convection coefficient, = 70 kJ/hr m2°C*
T_{in}	*indoor air dry-bulb temperature, °C*
C_{DT}	*coefficient dependent on system characteristics derived from regression (see below)*

The model uses the difference between the sol-air temperature and the indoor air dry-bulb temperature as a single independent variable to describe the hourly variation in distribution system efficiency. Table 1 below gives values for the seasonal sol-air temperature difference, $\Delta T_{sol,\ season}$, for the sixteen California climate zones.

Table 1 - Seasonal Sol-Air Temperature Difference, °F, by Climate Zone

Climate Zone	Cooling	Heating
1	23.00	-20.01
2	31.69	-23.64
3	23.66	-18.90
4	26.29	-21.13
5	26.02	-20.25
6	23.79	-17.12
7	25.17	-17.16
8	30.89	-19.46
9	32.73	-18.85
10	33.34	-21.53
11	34.24	-24.38
12	34.65	-23.31
13	34.53	-22.92
14	35.29	-25.64
15	33.33	-20.32
16	29.43	-29.86

The regression coefficient, CDT, is different for various values of duct insulation, duct leakage, and radiant barrier emissivity. For example, a duct with little insulation or large is more sensitive to attic temperature, and by association, to outdoor conditions. Similarly, attic construction also influences its value. An attic with a radiant barrier will have a lower attic temperature during cooling season, reflecting a smaller impact of sol-air temperature on distribution system efficiency. An analysis of this variation indicates that it is possible to combine the effects of duct insulation and duct leakage using the following relationship.

$$C_{DT} = C_0 + {C_R}/{R_{duct}} + C_L L_{duct}$$

Where:

C_{DT}	*coefficient dependent on system characteristics derived from regression (see below)*
R_{duct}	*duct insulation R-value, hr ft^2°F/Btu*
L_{duct}	*duct leakage as fraction of supply airflow, dimensionless*

Regression coefficients – see Table 2 below

Separate regressions have been performed for heating and cooling with and without a radiant barrier. The values of the coefficients are given in the table below.

Table 2 – Duct Efficiency Regression Coefficients

	Cooling		Heating	
	Radiant Barrier	No Radiant Barrier	Radiant Barrier	No Radiant Barrier
C_0	0.0078	0.0186	0.0350	0.0205
C_R	0.1222	0.0877	0.0794	0.1202
C_L	0.5480	0.2995	0.0714	0.2655

In summary, the proposed residential hourly duct/attic model equation is simple and uses only currently available weather and compliance inputs. The model is robust and while it may not recognize many subtle effects of building and HVAC system design and operation, it is unlikely to yield absurd results for any circumstance. The hourly distribution efficiency is always equal to the ACM manual seasonal distribution efficiency when the independent variable, ΔT_{sol}, is at its seasonal average value.

Residential Hourly Water Heating Models

Water heating energy in residences is regulated by the California building energy efficiency standards along with energy for space conditioning (heating and cooling). The energy budget is the sum of water heating and space conditioning energy, so that tradeoffs can be made between the two energy components. Energy use in the standard design and the proposed building is currently reported in source Btu per square foot per year. There is no consideration of when the energy is used. Space conditioning loads are calculated for each hour of the year, but water heating energy is calculated for the whole year. The current calculation procedures contained in the residential and nonresidential[1] ACM manuals yield only annual results.

As time dependent valuation (TDV) is used for assessing building energy performance, it is necessary to calculate water heating energy for each hour, like heating and cooling loads. As part of the hourly calculation method, it will be necessary to develop hourly schedules for hot water use, which would be inputs to the calculation method. If TDV is adopted, then it is mandatory that the water heating calculation method be revised, along with appropriate input assumptions.

As part of the TDV project, an hourly calculation method has been developed, which is a straightforward modification of the Load Dependent Energy Factor (LDEF) method already used. While the hourly water heating calculation procedure is rather straightforward, it means that the CEC must adopt additional standard modeling assumptions and these must be adopted in the residential ACM approval manual. The additional modeling assumptions include the following:

- Hourly schedules of hot water consumption.
- Characteristics of the “standard design” water heater.
- Other modeling assumptions such as the hot water set point and the inlet temperature.

Other hourly water heating models were explored, but they are not recommended for several reasons. The possible candidates (to use instead of the LDEF method) include the following:

WATTSIM This is a very detailed water heating model supported by EPRI. It accounts for such arcane inputs as the emissivity of the tank cladding and the density of tank insulation. While is considered to be extremely accurate, it is far more detailed than is reasonable for compliance purposes.

TANK This is a very detailed and extremely accurate model of the internal thermodynamics of gas water heaters. TANK is supported by the GRI and has been used by USDOE in the development of the national appliance standards.

[1] For nonresidential, there are actually two water heating methods. The method for high rise residential is identical to that for low-rise residential, while the method for nonresidential buildings uses the DOE-2 algorithms.

WHAM An alternative to the CEC procedure is the Water Heater Analysis Method (WHAM)[2] which was developed by LBNL and used for some of the calculations in the Technical Support Document (TSD) for the federal appliance proceedings. WHAM was developed as an alternative to complex utility industry-developed simulation programs such as TANK for gas water heaters and WATSIM for electric water heaters.

HWSIM This program is an event driven model that can be used to determine pipe losses in non-recirculating systems. This program is used to develop the California distribution system multipliers, but it is not used directly for compliance calculations.

Of the above models, WHAM was a serious contender, but since it requires inputs that are not commonly available, such as the input rating of the water heater, the tank volume, and the rate of conduction losses, it is not as appropriate for compliance calculations as the LDEF method, which only requires energy factor (EF).

Nonresidential HVAC Equipment Modeling Enhancements

The nonresidential ACMs already have equipment models that are capable of calculating the hourly energy use of air conditioners, heat pumps, furnaces and boilers. These models are incorporated in the reference method for nonresidential buildings, DOE-2.1E. While the model exists, the rules that are prescribed in the nonresidential ACM approval manual, do not offer any credit for equipment that performs better at peak temperature conditions or at unfavorable part load conditions.

To address this issue, we have developed a procedure for taking published data on equipment performance that is outside the range of test conditions used for ARI tests. Manufacturers publish performance data at 85ºF, 105ºF, 115ºF, and 125ºF, in addition to the standard ARI test condition of 95ºF. Data is also published for different entering wetbulb temperatures. The standard condition is 67ºF wetbulb. The procedure is to enter data at these extended conditions and an algorithm calculates a temperature dependent performance curve based on these data. This curve would be used for the proposed design, while a standard performance curve would be used for the standard design.

Compliance authors would have the choice of entering performance data for temperature conditions other than the 95ºF condition or using default curves. The default curves will be slightly punitive to encourage the use of the more advanced procedures.

Nonresidential Hourly Schedules Enhancements

Before 1992, the CEC nonresidential ACM approval manual had schedules of operation for about 10 different types of buildings. With the 1992 standards, these were consolidated into just two schedules: daytime and 24-hour. The latter 24-hour schedule is used for hotel guest rooms and other occupancies that are operated continuously. The nonresidential ACM manual lists scores of occupancies and indicates which of the two schedules are to be used with each.

With TDV, the schedules of operation becomes more important. As part of the TDV research, schedules have been developed for office, retail, assembly and schools. These schedules are determined from audits conducted as part of the development process for the NRNC database. It is recommended that the two standard schedules be expanded to at least five schedules. These schedules would be documented in the nonresidential ACM approval manual.

[2] Lutz, J., et al. "WHAM: Simplified Tool for Calculating Water Heater Energy Use." *ASHRAE Transactions* 5, no. 105, pt 1 (1999). American Society of Heating, Refrigerating, and Air-conditioning Engineers, 1791 Tullie Circle, Atlanta, GA 30329. Tel:(404)636-8400; Web site: www.ashrae.org.

Additional Modeling Enhancements

The TDV engineering model enhancements described in the previous paragraphs have been under development by the PG&E TDV team. Once the TDV economics methodology has been accepted by the CEC for use with Title 24, it is likely that others may propose additional engineering enhancements that provide more accurate hourly savings calculations for use with TDV. We assume that these will be discussed and adopted on their merits under the normal CEC standards review process.

TDV Economics Methodology

A detailed description of the TDV economics methodology and its derivation is attached as Appendix XX, a document entitled *Time Dependent Valuation (TDV) Formulation 'Cookbook'* (*TDV Cookbook* for short), dated March 15, 2002. This document is also available for download from the project web site: www.h-m-g.com – follow the hyperlink from the home page. What follows is a brief overview discussion of the TDV economics methodology.

Goals of Methodology

In developing the TDV methodology, we began with a review of the various ways that energy savings could be valued. A joint study by the CEC and PG&E, done in 1998-99, entitled *Dollar-Based Performance Standards*[3]*"*, looked at the forecast costs and the marginal costs for electricity, propane and natural gas, examined available sources of data, and explored the feasibility of using a dollar-based valuation scheme for Title 24. As a result of that study, we set several goals for the ultimate TDV methodology:

1. **Repeatable methodology –** the TDV valued would have to be updated from time-to-time, perhaps with each 3 year standards cycle, so it needs to have a clearly documented, repeatable method for developing the TDV factors.

2. **Publicly available data sources –** in order to be repeatable and defensible, the data inputs need to be available for public scrutiny

3. **Valid for a long-term efficiency perspective** – the Title 24 standards provide design signals for buildings that will have a life of 15 years, 30 years, or more. The TDV method should not reflect short term fluctuations in the energy markets, but should be based on reasonable, conservative, long-range forecasts of energy costs

4. **Not based on rates or tariffs** – while it is true that customers see rates, and the dollar savings they gain from efficiency investments are a function of those rates, rates to not provide a good basis for setting long-term efficiency goals statewide. Rates change by utility and often by year. Rates reflect many factors besides the costs of energy, including public policy (e.g. low-income assistance), customer class cross-subsidizations, utility marketing strategies, etc. TDV needs a basis that is more directly tied to the true costs of power to Californians, and that will be stable over time.

5. **Reflects the overall costs of energy** – TDV should not be based solely on the marginal costs of energy, which are lower than the total costs. If only the marginal costs were included, then the value of savings would be lower than Title 24 has traditionally valued savings, and the overall stringency of the standards would be reduced. By accounting for the total costs, by adjusting TDV valuation to reflect the total revenue requirements of the utilities, we more realistically value the savings of measures, and we also avoid back-sliding on the stringency of the Title 24 standards.

The historical, flat energy costing or valuation methodology of Title 24 assigns the same value to energy savings regardless of the time of day, season of year, temperature or any other of the differences known to affect the value of energy. By contrast, TDV assigns a different value for energy to each hour, depending on a variety of factors. Figure 3 compares the TDV and flat energy values for a representative summer weekday. Any point on the curve represents the value of a unit of energy savings for the given hour. Under TDV, energy saved during a peak hour

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[3] Heschong Mahone Group. *Dollar-Based Performance Standards for Building Energy Efficiency--Final Report*, 1999. For Pacific Gas & Electric Company.

has a higher value than the same savings under flat energy valuation; conversely, energy saved during an off-peak hour is valued less under TDV than under flat valuation.

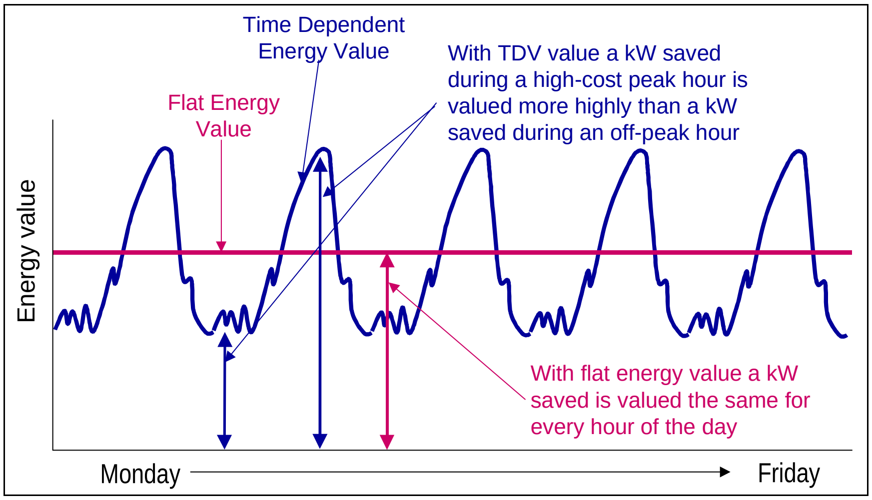


Figure 3 - TDV Costing Compared to Flat Costing – summer weekday

The consequences of TDV versus flat valuation follow from these observations. A measure whose savings are primarily during on-peak periods throughout the year would be more highly valued under TDV than under the present, flat valuation regime. An example of this would be high performance glazing in a west-facing window. Similarly, a measure whose savings are primarily during off-peak periods would be valued less than under TDV. An example would be economizer cooling, which provides free cooling during cool weather, but which does not operate during peak conditions.

Many measures, however, save energy all the time, and so over the course of a year are valued about the same under either TDV or flat valuation. For example, wall insulation reduces both heating and cooling loads, during both the summer and the winter, so the high and low TDV savings balance out. This is because the areas under the two curves in Figure 3 are equal over the full 8760 hours of the year.

Development of TDV Factors

The development of hourly TDV factors for electricity includes several components, as illustrated in Figure 4. It begins with the CEC's forecast for generation costs (labeled PX), which varies by month, day of week and time of day. Then it adds the transmission and distribution costs (T&D), which are assigned to the hottest hours of the year to reflect the fact that T&D costs are driven by peak temperature events. Next, the revenue neutrality adjustment is added, which brings the annual cost of energy into line with the statewide electric utility revenues, a proxy for the cost of electricity to ratepayers. Finally, an environmental externalities adder is applied, which reflects the cost of emissions from the least efficient power plants that are brought on-line during times of peak generation. The costs which are added up are life cycle costs, discounted back to present value assuming the CEC's standard 3% discount rate and a time period of 15 years for nonresidential buildings and 30 years for residential. The last step in the process is to convert the dollar values into equivalent energy values; these are analogous to the traditional source energy units used by the CEC for valuing energy savings.

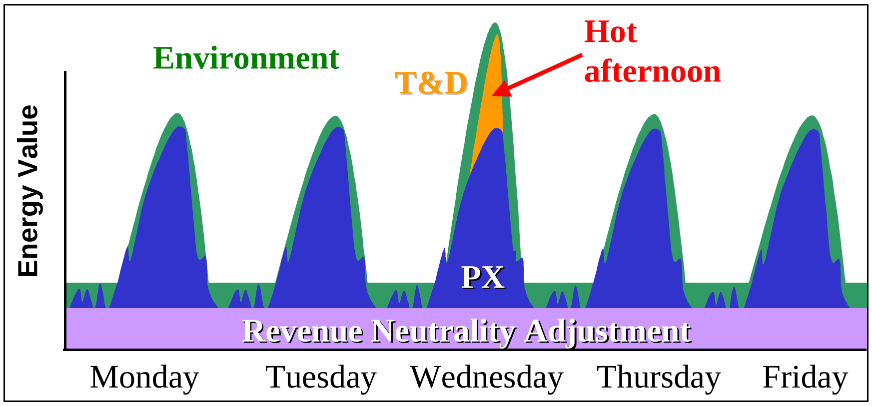


Figure 4 - Components of electricity TDV values during a hot summer week

This process produces a set of 8760 hourly values for the typical year represented by the weather tapes used for Title 24 energy analysis. Consequently, there are different sets of values for each of the 16 California climate zones. This is important, because these weather tapes are used in the hourly building energy simulations for Title 24 compliance, and it the peak conditions that the buildings experience in these models must match with the peak hours of savings valuation under TDV. A representative graph of the 8760 values for nonresidential buildings, using climate zone 13 data, is shown in Figure 5. These values are in present value dollars; they have not yet been converted into TDV energy units. This graph illustrates how the value of electricity savings is greatest during the hot, summer afternoon hours, and lowest during the winter months.

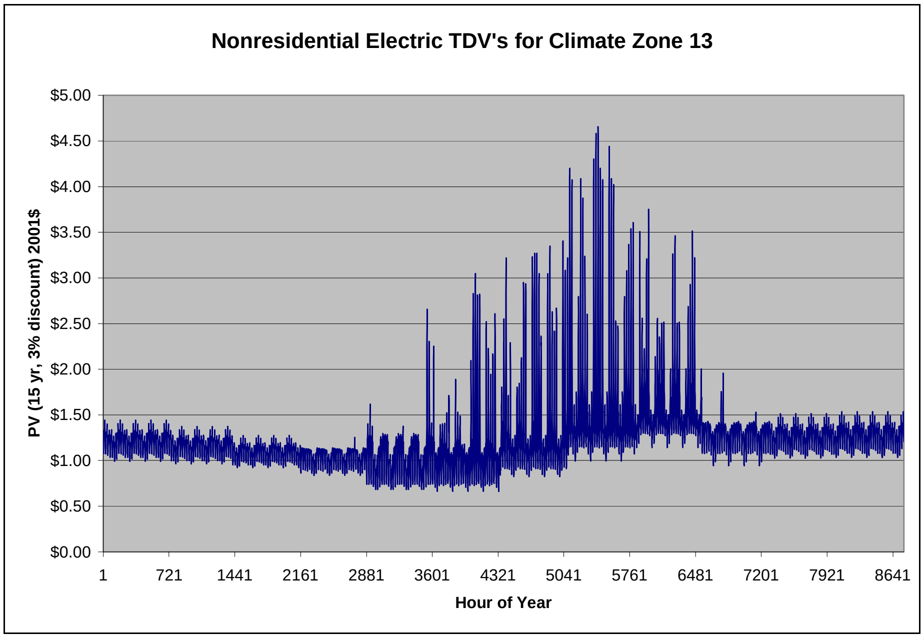


Figure 5 - Profile of TDV Electric Costs for CTZ 13

The process for generating natural gas and propane TDV energy values is similar to that for electricity, but it is simpler because they only vary monthly, not by day or by hour. The shape and components for the annual TDV values of gas are shown in Figure 6.

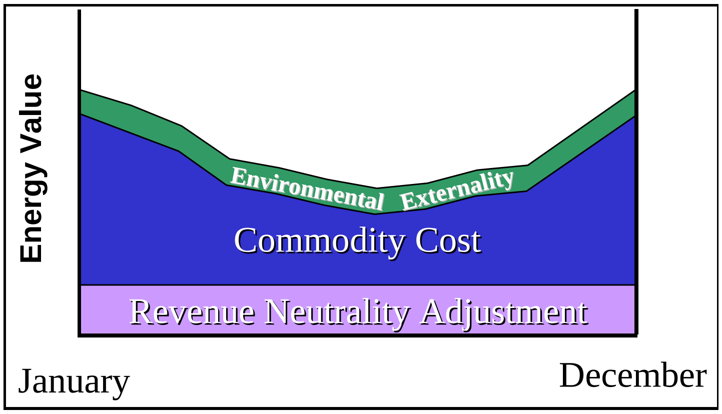


Figure 6 - Components of Gas TDVs

Environmental Externality Option

The environmental externalities parameter has been included for consistency with the CPUC's method for valuing energy savings in programs which use public benefits charge monies. It was developed using conservative assumptions of the costs of CO_2 and NOx, and, for electricity, associating these with the hours of peak generation in California. The environmental externality component of costs is applied uniformly to gas and propane energy savings, because CO_2 and NOx are generated whenever these fuels are consumed. The question of environmental externalities can be exceedingly complex and controversial, so our method has emphasized a straightforward and defensible approach. It would, of course, be possible to develop a more aggressive and complicated method. The net result of our approach is to increase the "peakiness" of electricity TDV factors. The portion of annual TDV savings attributable to the environmental externality will, of course, vary according to the measure and its time-of-savings characteristics. A representative comparison is shown in Figure 7, which compares the average life cycle cost valuation of a kWh of savings for a residential and a nonresidential building. The higher valuation for the residential case reflects the fact that a 30 year life cycle is assumed, versus a 15 year life cycle for nonresidential. The lower segment in each column is the generation component (Gen). The next segment is the transmission and distribution component (T&D), followed by the revenue neutrality adjustment (Retail). Finally, the top segment in each bar is the environmental externality component (Env). As with Figure 5, these are in units of LCC dollar valuations, before they are converted into TDV energy units.

Figure 7 illustrates the fact that the environmental externality is a small component of the overall TDV method. While we feel that including an environmental externality as part of TDV is warranted and reflects reality, we do not believe that it has a substantial effect on compliance outcomes or other Title 24 concerns, and it could be dropped without diminishing the fundamental value of TDV.

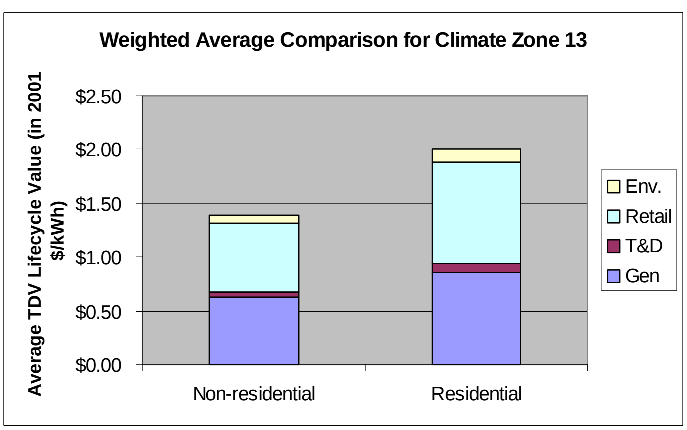


Figure 7 - Components of TDV Electric Values for Climate Zone 13

TDV Data Sources

The data sources used to derive the electricity, natural gas and propane TDV factors are listed in Table 3.

Table 3 - Data Sources Used in the TDV Methodology

Data	Source	Vary by Climate Zone?
Weather Data	Climate zone data used for standards evaluation	Yes - each zone has its own weather
Electric Class Shapes	1999 utility statistical load profiles used in billing	Yes - varies by utility
Electric Retail Rates Forecast	CEC forecast 2005 to 2034 for each IOU, res and non-res	Yes - varies by utility
Annual Wholesale Electric Price Forecast	CEC forecast 2005 to 2034 for each IOU	Yes - varies by utility
Hourly wholesale electric price shape	CEC (shape based on Richard Grix forecast)	No - system value used in all CZs
2005 Natural Gas Wholesale Price used in estimating electricity emissions component	CEC forecast average 2005 EG cost for each IOU	Yes - varies by utility
Emission rates by power plant type	E3 study	No
Emission costs by pollutant	E3 study	No
Natural Gas TDV Streams	CEC forecast retail gas rate - monthly 2005 to 2034 - residential and commercial	Yes - varies by utility
Oil Price forecast (propane assumed to follow oil price trend)	DOE EIA projection of oil prices through 2019, extended through 2034 by 10 year trend	No
Monthly propane price shape	DOE EIA Petroleum Marketing Monthly publication	No
Monthly propane consumption shape	DOE EIA Petroleum Marketing Monthly publication	No
Average propane price	DOE EIA Petroleum Marketing Monthly publication	No

A more complete and comprehensive description of the derivation of the TDV methodology, and the use of these data sources, is found in Appendix A, where the TDV Cookbook is reproduced.

Tables of summary statistics on the time dependent valuations derived for each of the sixteen California climate zones are presented in Appendix B. These tables indicate the ranges of present value numbers, in dollars, including minimum and maximum values, averages and standard deviations within the sets of 8760 hourly values.

One of the key aspects of the TDV economics methodology is the forecasts upon which the numbers are based. Over time, as available information is updated, the forecasters are likely to revise their forecasts, which should logically result in revised TDV numbers. As described in the TDV Cookbook, however, creating the TDV numbers is a multi-step task. Recreating the TDV numbers as forecasts change is not necessary nor recommended unless the forecasts have changed significantly. For slight changes in forecasted values of any of the fuels, one can multiply all the values by a scalar that adjusts the weighted average TDV's, as shown in Appendix B, up to the revised forecast value.

In addition to the derivation of the TDV economics values, shown in Appendix A, Appendix C contains a description of the method of conversion from TDV dollars (the LCC present value numbers used in previous discussions) into TDV energy units. This is the final step in the creation of the TDV numbers recommended for adoption into Title 24.

TDV Analysis Results

The development of TDV numbers is the heart of this proposal, but many stakeholders are more interested in how TDV will affect the Title 24 standards and compliance outcomes for real buildings. This section describes a suite of analyses conducted to try out TDV in a compliance-like setting, and to demonstrate how it affects the trade-off of measures and building features.

There is one major caveat that should be kept in mind in reviewing this analysis. Many of the details of the 2005 revisions to Title 24 are still under development, and so they may be changed in ways that cannot yet be anticipated. For example, if the CEC decides to change the way that the compliance tools calculate HVAC fan energy or part load performance, then the outcomes for Title 24 compliance might change. This would be true, of course, whether the old flat valuation scheme or the proposed TDV scheme of valuation is accepted. That said, it is still useful to see how the traditional flat valuation (herein referred to as “source energy” valuation) compares to TDV for a range of measure savings as they are currently calculated using Title 24 compliance tools. Doing so provides an understanding of how the time varying nature of TDV affects different kinds of measures, and makes it easier to anticipate how TDV might affect newer, proposed changes to Title 24.

The following sections summarize both residential and nonresidential analysis results. A full description of the analysis methodology and details of the results are presented in Appendix D.

Residential Analysis

The residential analysis was done using four example house designs provided by Consol, Inc. Each is a typical house, such as builders are constructing now. Each included a base case design and a series of measure parametrics, representative of the kinds of trade-offs that builders typically evaluate. In all, we examined the effects of 24 different measures, described below. The analysis was done for four climate zones: CTZ 6 (Long Beach, mild coastal), CTZ 12 (Sacramento, moderate Central Valley), CTZ 13 (Fresno, hot Central Valley), and CTZ 14 (China Lake, high desert).

Residential Methodology

The measures were evaluated using a research version of MICROPAS, the widely used residential compliance tool. We started with MICROPAS files for each of the example houses provided by Consol, Inc., and ran the measure parametrics using an automated procedure developed by Enercomp, Inc.

The research version of MICROPAS included the following enhancements over the compliance certified version. The most significant enhancement was the ability to capture the hourly outputs of the simulation and to apply the hourly TDV energy factors to each. In addition, the TDV runs used enhanced hourly HVAC, attic/duct, and water heating models, rather than the current Title 24 annual efficiency models for these measures.

Each parametric run was done as a compliance run, meaning that MICROPAS automatically generated the Title 24 standard case and calculated its energy use. The "as-designed" run was also performed for the base case design and for each parametric variation. The difference between these was the compliance margin, expressed as a percentage of the standard case.

The simulation results were then processed into summary graphs which facilitate comparison and understanding of the results

Example Houses

Small House

The small house is a 1290 sf house with one story. It has a total of 213 sf of window area (16.5% of the floor area) with 50 sf facing north, 24.8 sf facing east, 90 sf facing south, and 48 sf facing west. It has a 50 gallon gas water heater with an energy factor of 0.60, and a gas furnace with an AFUE of 80%.

In climate zone 06, the base case has an average SHGC of 0.70 and average U-value of 0.87. It has a SEER 10 AC unit; the ducts have R4.2 insulation. The roof has R30 insulation and the walls have R13 insulation. The water heater AFUE is 58%.

In climate zone 12, the windows have an average SHGC of 0.36 and a U-factor of 0.37. It has a SEER 10 AC unit; the ducts are tested and have R4.2 insulation. The roof has R38 insulation and the walls have R13 insulation with a layer of expanded polystyrene (EPS) for a total R-value of 17.2. The water heater AFUE is 58%.

In climate zones 13 and 14, the windows have an average SHGC of 0.36 and a U-factor of 0.37. It has a SEER 12 AC unit; the ducts are tested and have R4.2 insulation. The roof has R38 insulation and the walls have R13 insulation with a layer of expanded polystyrene (EPS) for a total R-value of 17.2. The water heater AFUE is 60%.

Medium House

The medium house is a 2190 sf house, with two stories. It has a total of 442 sf of window area (20.2% of the floor area) with 85.8 sf facing north, 7 sf facing northwest, 45 sf facing east, 207 sf facing south, and 98.3 sf facing west. It has a 50 gallon gas water heater with an energy factor of 0.60,and a gas furnace with an AFUE of 80%. The walls have R13 insulation and the roof has R38 insulation.

In climate zone 06, the base case has an average SHGC of 0.70 and average U-value of 0.70. It has a SEER 10 AC unit; the ducts have R4.2 insulation. The water heater AFUE is 60%. The walls have R13 insulation

In climate zone 12, the windows have an average SHGC of 0.34 and a U-factor of 0.28. It has a SEER 12 AC unit; the ducts have R4.2 insulation. The water heater AFUE is 60%. The walls have R13 insulation with a layer of expanded polystyrene (EPS) for a total R-value of 17.2

In climate zones 13 and 14, the windows have an average SHGC of 0.36 and a U-factor of 0.37. It has a SEER 12 AC unit; the ducts have R4.2 insulation. The water heater AFUE is 62% and the pipes insulated. The walls have R13 insulation with a layer of expanded polystyrene (EPS) for a total R-value of 17.2

Large House

The large house is a 3278 sf house with two stories. It has a total of 846 sf of window area (25.8% of the floor area) with 206.5 sf facing north, 185.8 sf facing east, 345.3 sf facing south, 9 sf facing southeast, 9 sf facing southwest and 91 sf facing west. It has a gas water heater with a 75 gallon storage tank with an energy factor of 0.60, an AFUE of 50% and a recirculation system. It has a gas furnace and a SEER 12 AC unit.

In climate zone 06, the windows have an average SHGC of 0.43 and a U-factor of 0.36. The furnace AFUE is 80%. The roof has R30 insulation and the walls have R13 insulation with a layer of expanded polystyrene (EPS) for a total R-value of 17.2.

In climate zone 12, the windows have an average SHGC of 0.43 and a U-factor of 0.36. The furnace AFUE is 90%. The AC unit has a TXV and the ducts are tested. The roof has R38 insulation and the walls have R13 insulation with a layer of expanded polystyrene (EPS) for a total R-value of 17.2.

In climate zones 13 and 14, the windows have an average SHGC of 0.43 and a U-factor of 0.36. The furnace AFUE is 90%. The AC unit has a TXV and the ducts are tested. The roof has R30 insulation and a radiant barrier and the walls have R13 insulation with a layer of expanded polystyrene (EPS) for a total R-value of 17.2.

Town House

The town house is a 1697 sf town house with two stories. It has a total of 316 sf of window area (18.6% of the floor area) with 52 sf facing north, 152 sf facing south, and 101 sf facing west. It has a gas furnace with an AFUE of 80% and a gas water heater with a 50 gallon storage tank with an energy factor of .60. It has R13 insulation in the walls.

In climate zone 06, the base case has an average SHGC of 0.70 and average U-value of 0.87. It has a SEER 10 AC unit; the ducts have R4.2 insulation. The roof has R30 insulation.

In climate zone 12, the windows have an average SHGC of 0.34 and a U-factor of 0.35. It has a SEER 10 AC unit; the ducts are tested and have R4.2 insulation. The roof has R38 insulation.

In climate zones 13 and 14, the windows have an average SHGC of 0.35 and a U-factor of 0.34. It has a SEER 12 AC unit; the ducts are tested and have R4.2 insulation. The roof has R38 insulation.

Residential Efficiency Measures

The measures evaluated are described in the following paragraphs. Please not that some measures are downgrades (i.e., use more energy and reduce the margin of compliance), while others are upgrades to the base case building. The measures represent typical trade-off candidates which builders may evaluate for use in their designs. The graphs in Appendix XX show the results which are discussed following each measure.

Measure 01 – Windows U0.50/S0.65

In Measure One the models have windows with an SHGC of 0.65 and a U-factor of 0.50. For all of the models except the small, medium and town houses in climate zone 06, this measure is a downgrade in glass. In the models where this was an upgrade, the improvement in compliance margin is greater for TDV than for source energy due to the effect that glass U-factor and SHGC has on cooling and the coincidence of cooling with peak loads.

The glass downgrade causes the other models to show a decrease in performance for both TDV and source energy; however, they all perform better under the TDV model (the large house in climate zone 13 only complies under the TDV method). This is due to the fact that all of the base cases have a larger compliance with the TDV energy method than with the source energy method. The models have other features besides glass that are improving the efficiency of loads that are coincidental with peak loads.

Measure 02 - Windows U0.65/S0.40

In Measure Two the models have windows with an SHGC of 0.40 and a U-factor of 0.65. The results of Measure Two show similar trends as Measure One. For the small, medium and large houses in climate zone, the performance of Measure Two is actually worse than Measure One, using the source energy method, while Measure Two performs considerably better than Measure One using the TDV method. Measure Two improves the SHGC of these three models, but lowers the U-factor. Since climate zone 06 is relatively temperate, the savings from the improved SHGC and cooling performance does not outweigh the loss from worsened heating performance due to decreased solar gains and insulation in the winter. However, since cooling loads are more coincident with peak than heating loads, the performance gains from cooling are greater than the losses from heating using the TDV method.

Measure 03 - Windows U0.35/S0.35

In Measure Three the models have windows with an SHGC of 0.35 and a U-factor of 0.35. The results of Measure Three are also similar to those of Measure One. Unlike Measure Two, even the small, medium and large houses in climate zone 06 improve with both the source energy and TDV energy methods since the U-factor is improved instead of worsened. Still, the TDV method shows greater savings due to the coincidence of cooling loads to peak.

Measure 04 – No Radiant Barrier

In Measure Four the models have no Radiant Barrier. None of the base cases except for the large house in climate zones 13 and 14 have radiant barriers. The removal of the radiant barriers from these models results in decreased performance in both the source energy and TDV energy methods. The impact is more pronounced with the TDV energy than the source energy method due to a radiant barrier's impact on peak coincident cooling loads.

Measure 05 – Radiant Barrier

In Measure Five the models have a Radiant Barrier. The addition of a radiant barrier (to all of the models except for the large house in climate zones 13 and 14) results in improved performance with both the source energy and the TDV energy methods, but the impact is greater for the TDV energy method due to the coincidence of cooling loads to peak. The impact is less pronounced for the models where the base case has R38 insulation in the roof than those where the base case has R30 insulation in the roof.

Measure 06 – R38 Ceiling

In Measure Six the models have R38 insulation in the roof. For the models whose base case has R30 insulation in the roof, this measure resulted in improved performance with both the source energy and the TDV energy methods. The measure resulted in more of a performance increase for the TDV energy method than the source energy method and the difference was more pronounced in the harsher climates with higher cooling loads than in more temperate climates except for the large house in climate zone 13. This model has a radiant barrier, which decreases the impact from the change in insulation level.

Measure 07 – R30 Ceiling

In Measure Seven the models have R30 insulation in the roof. Measure Seven had inverse effect of Measure Six. It resulted in worsened performance for the models whose base cases have R38 insulation in the roofs. The magnitude of the impact was similar to that of Measure Six. Also like Measure Six, the large house in climate zone 14 has a radiant barrier, which reduces the impact of the change in insulation level.

Measure 08 – R19 Ceiling

In Measure Eight the models have R19 insulation in the roof. The decrease in ceiling insulation results in worsened performance with both the source energy and TDV energy methods. The impact is greater for the TDV energy method due to the coincidence of cooling loads to peak. The impact is also greater for models that have R38 roof insulation in the base case and models in harsher climates such as climate zone 14.

Measure 09 – Wall R13

In Measure Nine the models have R13 insulation in the walls. For the models whose base case has a layer of EPS, Measure Nine results in a worsened performance for both the source energy and the TDV energy methods. The magnitude of change was greater for the TDV energy than the source energy method. The difference, however, was small, but greater in climates with larger cooling loads. This shows that the effect of the measure on loading is coincidental with peak loading, but not to a large degree.

Measure 10 – Wall R13 w/ Foam

In Measure Ten the models have R13 insulation in the walls and a layer of EPS for a total R-value of 17.2. The results for Measure Ten are inverse of those of Measure Nine. For those cases with R13 walls, Measure Ten results in improved performance with both the source energy and the TDV energy methods. The base cases that had R13 walls were in more temperate climates or townhouses, so the magnitude of the difference between the source energy method and the TDV energy method is not as great.

Measure 11 – Wall R19

In Measure Eleven the models have R19 insulation in the walls. For the climate zones whose base cases have R13 walls, Measure Eleven results in a greater improvement in performance with the TDV energy method than the source energy method. This reinforces that the effects of wall insulation are coincidental with peak loading.

For the climate zones whose base cases have R17.2 walls, Measure Eleven results in little, if any difference from the base case; for the climate zones whose base cases have R13 walls, the results of Measure Eleven show little, if any difference from Measure Ten. Therefore, a difference of R1.8 in the walls seems to have little effect.

Measure 12 – AC TXV

In Measure Twelve the models have a TXV on the AC unit. The addition of a TXV to the models with no TXV in the base case results in an improvement over the base case. The improvement is not significant and the improvement using the TDV energy method is only slightly greater than source energy method.

Measure 13 – AC SEER 12

In Measure Thirteen the models have a SEER 12 AC unit. Measure Thirteen increases the efficiency of the AC units to 12 (except for those that are already SEER 12). The resulting improvement is far more pronounced for the TDV energy method than the source energy method showing the effect of AC efficiency on peak coincident heating loads. The improvement in performance is most pronounced in climate zone 14 which has the highest cooling loads of the climate zones analyzed, and least pronounced in climate zone 06 which has the lowest cooling loads of the climate zones analyzed.

Measure 14 – AC SEER 14.4

In Measure Fourteen the models have a SEER 14.4 AC unit. Measure Fourteen improves the efficiency of the AC units to SEER 14.4. The improvement is more pronounced for the models whose base cases have 10 SEER AC units and the improvement is also greater with the TDV energy method than with the source energy method sue to the coincidence of cooling loads with peak. For the models whose base cases have 12 SEER AC units, the performance improvement is very similar for both the source energy and the TDV energy method. So the efficiency improvements from SEER 12 to SEER 14.4 is not very coincidental with peak unlike the improvement from SEER 10 to SEER 12.

Measure 15 – Furnace AFUE 90

In Measure Fifteen the models have a gas furnace with an AFUE of 90%. The furnace AFUE was increased to 90% for all of the models except for the large house in climate zones 12, 13 and 14. The improvement is more pronounced in the small house in climate zones 06 and 12 whose base case have a furnace AFUE of 78% instead of 80%. The source energy and TDV energy methods produce similar improvements since heating loads are not very coincidental with peak loads.

Measure 16 – Duct R6

In Measure Sixteen the models have ducts with R6 insulation. Increasing the duct insulation from R4.2 to R6 improves the performance of all of the models in all of the climate zones. The performance is most improved in climate zone 14, which has the harshest climate. In climate zone 06, which has the mildest climate, the source energy and TDV energy methods produce similar results; however, in the harsher climates, the discrepancy between the source energy and TDV energy methods broadens showing that duct insulation has some effect on peak coincidental loads.

Measure 17 – Duct R8

In Measure Seventeen the models have ducts with R8 insulation. The increase in duct insulation to R8 results in improved performance for all of the models in all of the climate zones. The improvement is more pronounced in the harsher climate zones than the milder zones such as 06. The improvement from improving R6 to R8 is not as great as the improvement from improving R4.2 to R6. The improvement for the source energy and TDV energy methods is of similar magnitude.

Measure 18 – Tight Ducts

In Measure Eighteen the models have tight ducts. The addition of tight duct to the models whose base cases do not have tight ducts results in improved performance. The improvement is greater in the harsher climate zones and more pronounced with the TDV energy method than the source energy method meaning that duct tightness has an effect on peak coincidental loads.

Measure 19 – ACCA Ducts

In Measure Nineteen the models have ACCA standard ducts. The addition of ACCA standard ducts results in worsened performance in the small house in climate zone 06; in all of the other models, it results in improved performance. Performance is improved more in the climate zones that have a harsher climate and is similar for both the source energy and TDV energy methods. ACCA ducts do not produce as much of a performance improvement as tight ducts.

Measure 20 – DHW EF 0.60/50Gal

In Measure Twenty the models have a gas water heater with a 50 gallon storage tank and AFUE of 60%. Measure Twenty results in a slight improvement in performance for the models whose base cases have an AFUE of 58%. The measure results in a decrease in performance for the models whose base cases have an AFUE of 62%; however, the decrease in performance is only slight. The base cases for the large house have a 75 gallon tank and an AFUE of 50% and the more efficient water heater and smaller tank result in greater savings.

Measure 21 – DHW EF .62/40Gal

In Measure Twenty-one the models have a gas water heater with a 40 gallon storage tank and AFUE of 62%. The increase in efficiency results in improved performance for all of the models except the medium house in climate zones 13 and 14 which already have a heater efficiency of 62%. The improvement is the same for the source energy and TDV energy models.

Measure 22 – DHW Pipe Insulation

In Measure Twenty-two the models have insulation on the water pipes. The addition of pipe insulation improves the performance of all of the models. The improvement is greater for the models with lower base case efficiencies or higher water heating loads. The improvement is the same for the source energy and TDV energy models.

Measure 23 – Glass Area –10%

In Measure Twenty-three the models have 10% less glass area. The decrease in window area results in improved performance for all of the models. The measure has greater impact in the harsher climates and the impact is greater for the TDV energy method than for the source energy method. The measure has a greater impact on the larger houses since they have larger window to floor areas and the measure results in disproportionately larger windows for those models.

Measure 24 – Glass Area +10%

In Measure Twenty-four the models have 10% more glass area. The increase in window area results in worsened performance for all of the models. The measure has greater impact in the harsher climates and the impact is greater for the TDV energy method than for the source energy method. The measure has a greater impact on the larger houses since they have larger window to floor areas and the measure results in disproportionately larger windows for those models.

Residential Analysis Results

The bottom line for each parametric run was the margin of compliance, expressed as a percentage of energy use below the Title 24 standard case (or, in the case of a negative compliance margin, above standard). For example, if a run calculated the standard case energy at 18, and the parametric run energy at 16, then the compliance margin for energy would be 2, or 2/18= 11% better than standard case.

The compliance margin for each parametric was calculated two ways: using the traditional Title 24 source energy method, and using the proposed TDV method. In each of the results graphs, the source and TDV compliance margins are displayed side-by-side. In cases where the measure performed better on-peak, the TDV compliance margin would be larger than the source compliance margin. In other cases, where the energy savings occur all the time, they would have the same compliance margin.

In each set of parametrics, there are some measures which are the same as the base case house design, and so there is no energy savings for that measure in that case. These are indicated by no bars on the graph, and by an asterisk next to the label on the graph for the measure.

Comparing the magnitudes of the compliance margins for different measures gives a concise indication of how trade-offs might be explored. For example, if reducing the efficiency of one measure, perhaps the efficiency of the window glazing, gives a negative compliance margin of 7%, then this would have to be offset with the addition of another measure with a positive compliance margin of 7% or more. These kinds of trade-offs are typical within the compliance arena, because they allow builders to choose the efficiency measures that they feel are most cost effective and satisfactory to build for their particular house design and site.

A typical set of graphs is shown on the following page, as Figure 8 and Figure 9, for the medium house in climate zone 14 (China Lake high desert). All of the analysis graphs are found in Appendix D. Some observations to illustrate how these graphs could be read:

- Some of the measures are included in the base design. For example, it has no radiant barrier and the walls have R13 foam insulation.
- The starting design (base) for this house has about a 2% compliance margin under the traditional source energy valuation. Under TDV, it would have about a 7% compliance margin.
- The first measure, windows with a U-factor of 0.50 and a SHGF of 0.65, indicates worse window properties than the prescriptive requirement for this climate zone, so there is a negative compliance margin for this measure (-17% under source valuation; -12% under TDV). For this house, the compliance margin is more negative under source valuation than under TDV. To compensate for this measure under source valuation, the builder might have choose to use several measures with positive compliance margins. Under TDV, at least two measures would be called for, but most measures in this case are more highly valued by TDV than by source valuation.

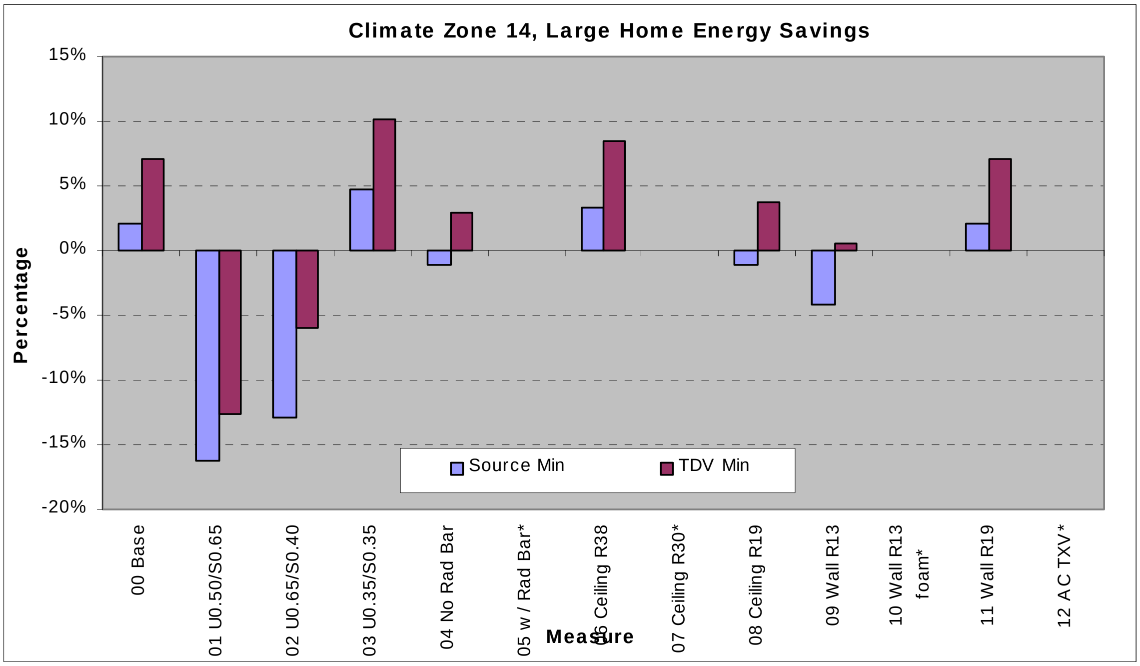


Figure 8 - CTZ 14, Large Home, Part 1

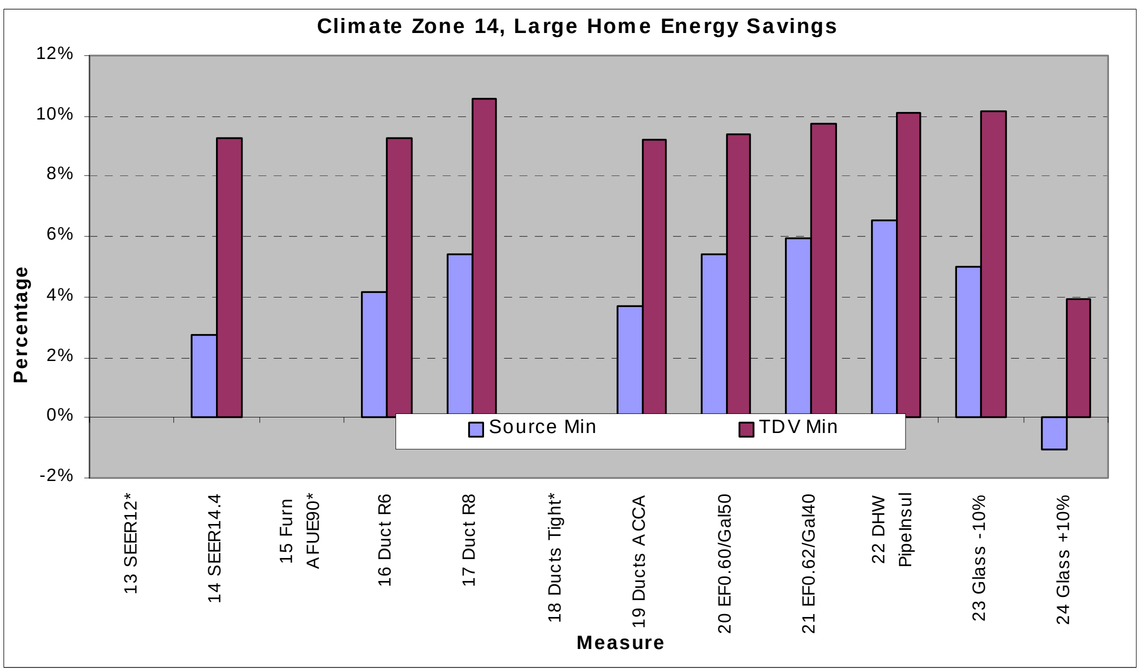


Figure 9 - CTZ 14, Large Home, Part 2

A common practice in residential compliance by production builders is to use the “cardinal orientation” method, wherein a given house design is modeled facing the four different cardinal orientations. As long as the design complies under the worst orientation, the design may be built facing any orientation. All of the residential parametric analysis described above was done using this method. The consequences of TDV for this approach have been evaluated for all four house designs in CTZ 14; the large home graph is reproduced below (see the end of Appendix D for the others).

In this analysis, the house design has been run for 6 parametrics, and the results from the worst and best orientations are shown for each. All results are shown in terms of compliance margin, as in the graphs above. By “worst”, we mean having the lowest compliance margin, labeled “Min”, and by “best” we mean having the highest compliance margin. In each group of bars, the left two show the min and max under source energy (flat) valuation, and the right two show the min and max under TDV.

For this example, the base design shows that the minimum compliance margin for source valuation is about 2%, while the minimum TDV compliance margin is about –3%. On the other hand, the maximum source compliance margin is about 9% while the maximum TDV compliance margin is about 7%. For all of these parametrics, the minimum TDV margin is worse than the minimum source margin, which indicates that this design is more sensitive to orientation effects under TDV. This result will likely be more significant for house designs that have significant orientation differences, such as one side of the house with large glass areas. Results will vary, of course, depending on climate zone and features of the house.

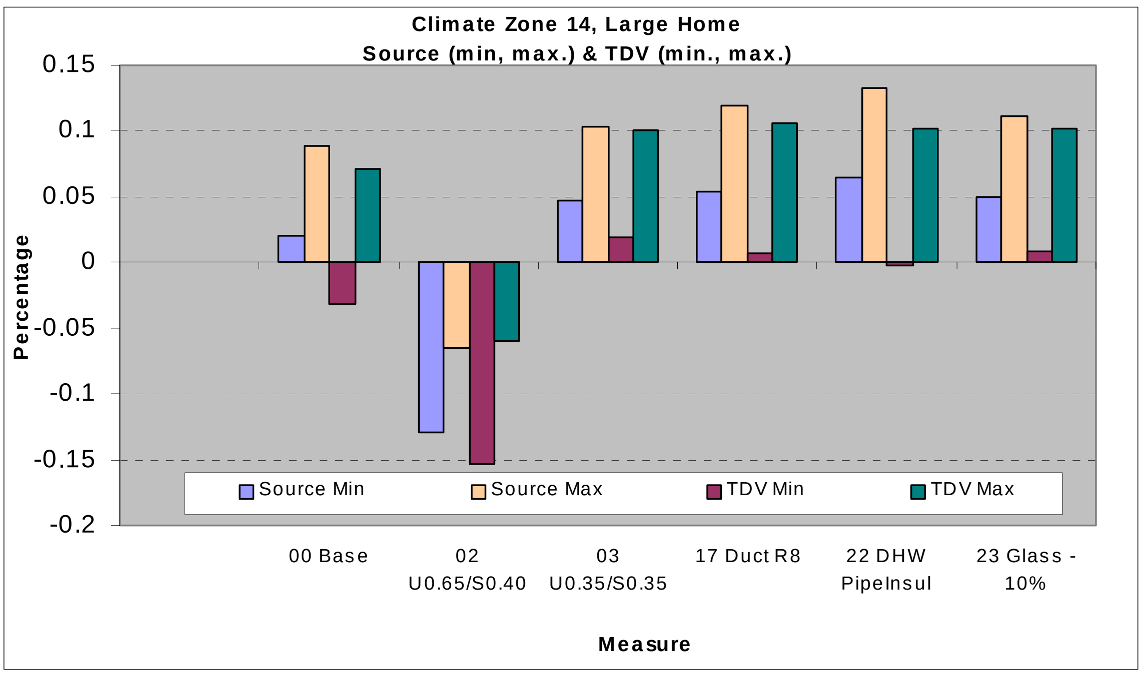


Figure 10 - CTZ 14, Large House, Min/Max Orientation Comparisons

Nonresidential Analysis

Nonresidential Methodology

The method used to compare the impact of a time dependent valuation (TDV) with other forms of energy valuations is as follows.

1. Energy simulations were performed using the Energy Pro performance method software for four major building types covered by the nonresidential and high-rise residential efficiency standards – Offices, Retail, School and Hotel. To evaluate the statewide impact of TDV, these building models were simulated in four climate zones with widely differing climates- CTZ 6 Long Beach (south coastal), CTZ 12 Sacramento (mild central valley), CTZ 13 Fresno (hot central valley), and CTZ 14 China Lake (high desert). The TDV research version of Energy Pro writes a separate file of hourly electricity and fuel consumption.

2. The hourly inputs are processed by the nonresidential TDV spreadsheet (nonresTDV2.xls)[4]. The TDV spreadsheet applies the hourly "TDV energy multipliers" so that all forms of energy are converted into nominal TDV energy units. The spreadsheet then summarizes the results in terms of site energy, source energy, TDV with natural gas and TDV with propane.

3. The measure summaries from the TDV spreadsheet are imported into the measure comparison spreadsheet. This comparison spreadsheet also calculates a flat valuation to compare with the other reporting formats and then graphs the results as shown Appendix E.

Nonresidential Base Case Buildings

The energy simulation tool used for this project is the special research version of EnergyPro (ver 2.3) prepared by Energy-Soft. This version is based upon the 1998 Title-24 standards. Accordingly, simulations carried out for this study are based upon the 1998 standards as implemented in EnergyPro.

In this analysis, we used the schedules (for occupancy, lighting plug loads etc.) as defined in the ACM. These schedules do not vary by building type so that the differences in energy consumption and peak loads between building types are less than one would expect.

Where variables are not defined by the building standards, the base case building descriptions are derived from the 1999 State-Wide Unit Energy Savings Project Report, submitted by James J. Hirsch & Associates, Camarillo, California. The report documents the methodology and results of parametric analyses conducted in an effort to provide a ‘systems’ approach under the statewide 1999 non-residential new construction *Savings by Design* program.

To size mechanical systems, EnergyPro is initially run in a non-compliance mode to calculate building loads reported by the zone. The peak loads are then used to determine system capacity. The system description along with proper capacities is then input in the building description, and the analysis run in compliance mode, to get compliance information.

The following sections describe in detail the building inputs for each building type. For a given building type these inputs are a function of climate zone. As an example, more insulation is required in colder climates and lower solar heat gain coefficients for glazing are required in hotter climates.

[4] This spreadsheet is available from the TDV website: http://www.h-m-g.com/TDV/index.htm

Office Building – Base Case

The office building is assumed to be an open-plan configuration, with total area of 117,000 sf distributed evenly over 6 floors.

Table 4 - Office Building Base Case Characteristics

OFFICE building - Base Case Building Description -1998 Standards						
		Climate Zone				
Architectural Features		**1,16**	**2-5**	**6-10**	**11-13**	**14, 15**
Conditioned Area (sqft)	117,000.00					
Number of Stories	6					
Roof R-value		19	19	11	19	19
Opaque Wall R-value		13	11	11	13	13
Floor Slab Insulation		19	11	11	11	11
Vertical Glazing						
U-factor		0.72	1.23	1.23	0.72	0.72
Shading Coefficient						
North		0.77	0.82	0.82	0.77	0.77
Non-North		0.50	0.62	0.62	0.50	0.50
Area (% of Gross Wall)	30					
Skylights						
U-factor		na	na	na	na	na
Shading Coefficient		na	na	na	na	na
Visible Transmittance		na	na	na	na	na
Area (% of Floor)	na					
Internal Loads						
Lighting Density (W/sf)	1.2					
Equipment Density (W/sf)	1.34					
Occupant Density (sqft/person)	100					
HVAC						
Cooling Setpoint (Deg. F)	74					
Heating Setpoint (Deg. F)	70					
Base System (Title 24)						
Type	Builtup VAV	Note - Based upon the standard CEC system for High-rise Non-residential building (Source - 1998 ACM Manual Figure 2-1)				
Outside Air Supply (cfm/sqft)	0.15					
Economizer Control	None					
Chiller Efficiency (kW/ton)	1.00					
Boiler Efficiency (EF)	0.85					
Motor Efficiency	High Efficiency					
Heating Type	Hot Water					
Coil Control	Constant Temperature					
Reheat Coil	Hot Water					
Reheat Coil Air Delta	50					
Cooling Coil Control	Warmest Zone					
Supply Temp	55					
Fan Control	Continuous					
Hot Water						
Gas Heating	Standard 50 Gallons					

Notes:
- Values taken from the 1998 Title-24 standards
- Text in Red are values that are taken from the 1999 State-Wide Energy Savings Project
- Values in blue are assumptions of this study

1. The building plan is assumed to be rectangular, with the length to width ratio of 2:1, with the longer sides facing North-South.

2. Zoning: The building will be analyzed as a simple 'box' building and will be zoned by a perimeter – core configuration. Thus there will be four perimeter zones. Depth of the perimeter zone will be 30

feet. Areas for the perimeter zones are calculated based upon the ‘trapezoid’ method used by VisDOE. All the zones are served by one VAV system.

EnergyPro uses default system types to generate the standard case, based upon the geometric information fed into the proposed base case. Attempt has been made to mimic those systems in the proposed base cases, by comparing the BDL files for the standard and proposed base cases, and making appropriate changes in the proposed case HVAC system description.

For the office building a built-up VAV system was designed based upon the UES study, and then modified to conform to the standard case descriptions generated by EnergyPro.

The central chiller is a scroll type, 50-ton electric chiller, with a 50 ton cooling tower with a two-speed fan. The central boiler is a 20000 Btu/hr with 0.85 energy factor. At the zone level VAV boxes with a 30% minimum airflow are specified.

Retail Building – Base Case

The retail building is assumed to be a big-box, single floor space with an area of 50,000 square feet. The building is analyzed as a single zone and is fed with a VAV system.

Table 5 – Retail Building Base Case Characteristics

0109 - TDV Energy Simulations

RETAIL building - Base Case Building Description -1998 Standards

			Climate Zone				
Architectural Features			**1,16**	**2-5**	**6-10**	**11-13**	**14, 15**
Conditioned Area (sqft)		50,000.00					
Number of Stories		1.00					
Roof R-value			19	19	11	19	19
Opaque Wall R-value			13	11	11	13	13
Floor Slab Insulation			19	11	11	11	11
Vertical Glazing							
	U-factor		0.72	1.23	1.23	0.72	0.72
	Shading Coefficient						
	North		0.77	0.82	0.82	0.77	0.77
	Non-North		0.50	0.62	0.62	0.50	0.50
	Area (% of Gross Wall)	2.7%					
Skylights	(Translucent)						
	U-factor		0.85	1.31	1.31	0.85	0.85
	Shading Coefficient		0.70	0.75	0.75	0.70	0.70
	Visible Transmittance		0.27	0.37	0.37	0.27	0.27
	Area (% of Floor)	3%					
Internal Loads							
Lighting Density (W/sf)		1.70					
Equipment Density (W/sf)		0.94					
Occupant Density (sqft/person)		34.50					
HVAC							
Cooling Setpoint (Deg. F)		74					
Heating Setpoint (Deg. F)		70					
Base System (Title 24)							
Type		Packaged VAV	Note - Based upon the standard CEC system for High-rise Non-residential building (Source - 1998 ACM Manual Figure 2-1)				
Outside Air Supply (cfm/sqft)		0.23					
Economizer Control		None					
Chiller Efficiency (kW/ton)		1.00					
Boiler Efficiency (EF)		0.85					
Motor Efficiency		High Efficiency					
Heating Type		Gas Furnace					
Coil Control		Constant Temperature					
Reheat Coil		Hot Water					
Reheat Coil Air Delta		50					
Cooling Coil Control		OA Reset					
Supply Temp		55					
Fan Control		Continuous					
Hot Water							
Gas Heating		Standard 50 Gallons					

Notes:
- Values taken from the 1998 Title-24 standards
- Text in Red are values that are taken from the 1999 State-Wide Energy Savings Project

1. The building plan is assumed to be square. All sides are equal.

2. Zoning: The building is analyzed as a simple ‘box’ building with one zone covering the entire floor area. This is a simplification based upon the assumption that the area being analyzed is the sales floor.

For the retail building a packaged VAV system was designed based upon the UES study, and then modified to conform to the standard case descriptions generated by EnergyPro.

The central chiller is a screw type, 100-ton air-cooled electric chiller. The central boiler is a 950000 Btu/hr with 0.85 energy factor. At the zone level VAV boxes with a 30% minimum airflow are specified.

Nonresidential Efficiency Measures

The base cases for the four building types mentioned above are to be run for four climate zones - CTZ 6 Long Beach (south coastal), CTZ 12 Sacramento (mild central valley), CTZ 13 Fresno (hot central valley), and CTZ 14 China Lake (high desert)

The measures to be analyzed are:

1. Gas Cooling
2. Increased Cooling Efficiency
3. Economizer ON
4. Cool roof
5. Changing window SHGC on South and West windows
6. Efficient (low LPD) lighting

Gas Cooling Analysis

This measure looks at the relative time-dependant performance of Electric Chillers versus Gas fired Chillers. The base cases use an Electric Chiller in the system description, as per the 1998 ACM manual.

1. **Office Building** – The office base case uses a built-up VAV with electric chiller. In this measure the electric chiller was replaced with a gas-engine driven chiller with the same capacity. The gas-engine driven chiller has a COP of 1.70.

2. **Retail Building** – For this building type, the base case is a packaged VAV (1998 ACM Manual). Hence it is not possible to input a chiller description. To allow comparable analysis to the office case, a special base case was generated for the retail building just for this measure. This measure base case used a built-up VAV system comparable to the office base case. The measure was then analyzed by replacing the electric chiller with a gas-engine driven chiller as above. The efficiency gains for this particular measure are therefore measured against the special base case as opposed to the base case described in the previous section.

Results - There are some coincident peaks involved with this measure, and is reflected in the TDV savings. However, the majority of the TDV savings percentage comes from the difference in valuation of electricity and gas.

Increased Cooling Efficiency

This measure looks at the time-dependant effects of increasing cooling efficiency of the HVAC system. Each building type uses a different system based upon the UES study findings and the 1998 ACM Manual. A summary of the measure for each of the building types follows:

1. **Office Building** – The base case used for this building type is a built-up VAV system. For this measure the electrical chiller efficiency was increased from 1.00 kW/Ton to 0.72 kW/Ton.

2. **Retail Building** – The base case for this building type uses a Packaged VAV system. For this measure, the EER for the cooling was increased from 8.90 to 9.60.

Results - Similar to the gas cooling measure, this measure has some coincident peaks, which are reflected in the difference between Source and TDV savings. Since this is an all electric measure, the difference between source and TDV is not as wide as in the gas cooling measure.

Economizer ON

This measure looks at the time-dependant effects of using economizers in the HVAC systems for each of the building types. The base cases for all the building types do not have economizer operation enabled. This is because the equipment capacity and cfm in the space is lower than those required by code specifications (total mechanical cooling capacity over 75000 Btu/hr and supply capacity over 2500 cfm) for economizer operation. The efficiency measure activates the economizer operation and uses a differential temperature (integrated) type of economizer operation.

Results - Energy savings from economizers occur mostly at of-peak hours, and hence there are no TDV peak savings. This is reflected in TDV savings being smaller than source savings in all climate zones.

Cool Roof Credit

The base cases for all building types use the title 24 default roof assembly as per the ACM manual. The Cool Roof credit is taken in the form of a reduced absorptance value for the roof assembly – 0.45 instead of the 0.70 in the standards.

Results - This measure has a coincident peak and reduced cooling loads, which is reflected in the higher TDV savings as compared to the source energy savings. Also, the savings are greater in warmer climates, since this measure is a cooling load reduction measure.

Lower SHGC values for south and west facing windows

This measure looks at the effect of changing the SHGC only for the two orientations, since they are the principal sources of solar gains. The SHGC is reduced by 20%.

Results - This measure results in smaller cooling loads, and slightly higher cooling loads. Since the retail building has very small window area there are no perceptible savings from this measure. Office, which has higher window areas shows savings in both source and TDV energies.

Low Lighting Power Density (LPD)

The base cases use title24 specified LPD values for various occupancies. This measure looks at the impact of using higher efficiency lighting systems, by using a 20% lower LPD.

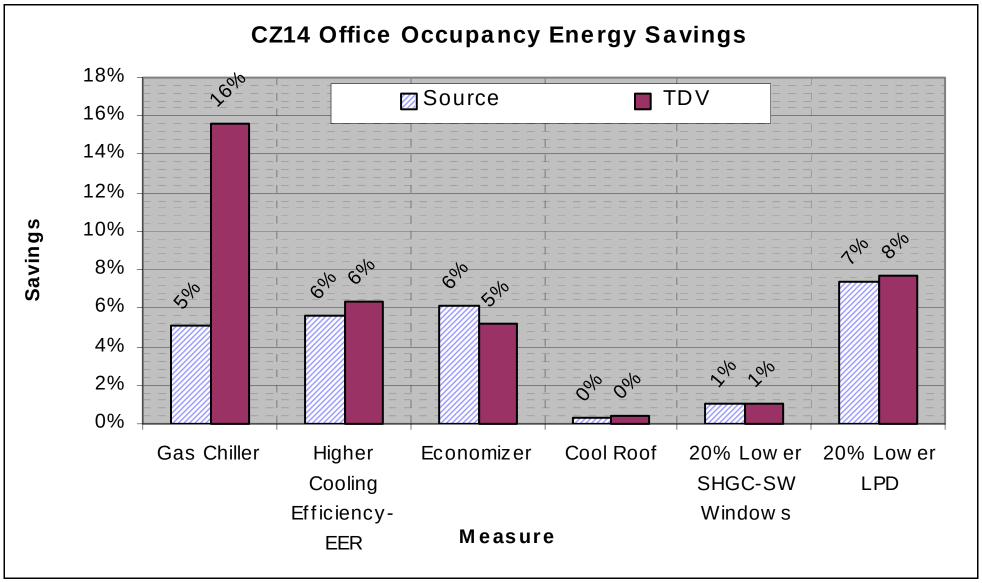
Results - Retail has higher lighting loads than the office, and hence shows greater reduction in lighting energy use due to lower LPD. This is reflected in the TDV and flat valuation savings. Because the lighting schedule of 8 am to 5 pm weekdays is somewhat coincident with system peaks, the measure has some peak load savings which are reflected in TDV savings being greater than savings calculated using flat valuation.

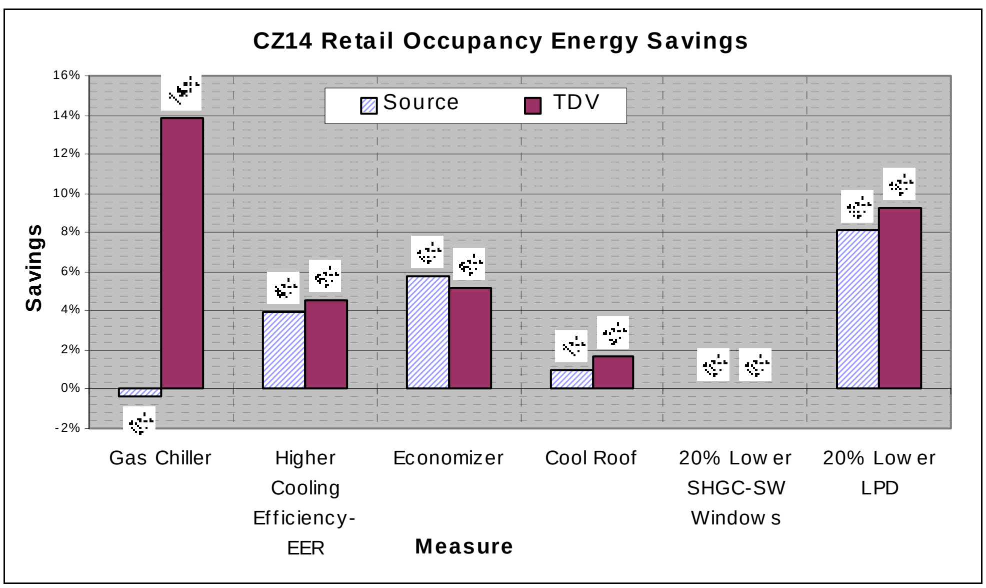
Nonresidential Analysis Results

The results, discussed in general terms above, are described graphically in the nonresidential analysis results graphs. A sample of two of these graphs is shown on the following page, with the results for both the office and the retail parametrics run for climate zone 14 (China Lake, high desert). As with the residential graphs shown in the previous section, these graphs show the compliance margin for each measure, expressed as a percentage of energy below the

Title 24 base case. This means that a measure having positive compliance margin uses less energy than the base case. The two columns in each set represent the compliance margin under the traditional source energy valuation, and the compliance margin under TDV.

For several of the measures in these examples, the compliance margin is similar for the two valuation schemes. A dramatic difference is noted for the gas cooling measure, which actually shows a negative compliance margin under source energy, but a large compliance margin under TDV. As noted above, this difference is largely due to the fact that gas is valued relatively higher compared to electricity under source energy valuation; that, plus the fact that changing from electric to gas cooling avoids the higher on-peak cooling energy valuation for electricity. Economizer cooling, by contrast, is valued less under TDV because it operates primarily under off-peak conditions.





TDV Analysis Results - General Conclusions

From inspection of the results of this analysis, the following general comments can be made:

- For measures that involve electricity savings, TDV savings are significantly higher than those from source energy comparisons. There are two components of this additional savings:

- Source energy uses a ratio of 3:1 to compare natural gas and electricity, yet the average value of electricity used for evaluating the cost-effectiveness of the standards is 4:1 and up. TDV is based upon the economic valuations and gives a higher value to electricity even if time and temperature dependency were not included.

- Most of the electricity savings measures tended to save more during the times of peak and thus were valued yet higher than by a mere comparison of the average value of energy sources.

We conclude that TDV is giving the correct kinds of signals to the construction market to design buildings that reduce peak demand. The California efficiency standards should incorporate TDV into the cost-effectiveness analysis of prescriptive requirements and the performance methods as defined in the Alternative Compliance Method (ACM). This will ensure that the two methods are in concordance and simplify moving trade-off measures typically chosen by designers into the prescriptive standards.

Recommendations

We recommend that the CEC adopt the TDV economics values and methodology, as documented in the report, *Time Dependent Valuation (TDV) Formulation 'Cookbook'* (*TDV Cookbook* for short), dated March 15, 2002. A copy of this document is attached as Appendix F.

Proposed Standards Language

The primary change to the Standards for TDV would be to replace the definition of Source Energy. The existing definition:

> ~~**SOURCE ENERGY**~~ is the energy that is used at a site and consumed in producing and in delivering energy to a site, including, but not limited to, power generation, transmission and distribution losses, and that is used to perform a specific function, such as space conditioning, lighting or water heating~~. Table 1-B contains the conversion factors for converting site to source energy.~~ (and Table 1-B would deleted)

This would be replaced with the following proposed definition:

> **<u>TDV ENERGY</u>** <u>(TDV means time dependent valuation)</u> is the energy that is used at a site and consumed in producing and in delivering energy to a site, including, but not limited to, power generation, transmission and distribution losses, and that is used to perform a specific function, such as space conditioning, lighting or water heating. <u>The value of TDV energy is determined by multiplying the hourly site energy values for a design by the associated hourly TDV factors. These are energy valuation factors for each hour of a typical year, for electricity, natural gas and propane energy sources. These hourly factors are specific to each of the sixteen California climate zones, and are distinct for residential and nonresidential occupancies. The hourly TDV factors are defined in CEC Report #XXXX.</u>

Also, the definition for “Energy Budget” would be amended as follows:

> **ENERGY BUDGET** is the maximum amount of ~~source~~ <u>TDV</u> energy that a proposed building, or portion of a building…

Additional changes would be needed to reflect the fact that TDV treats propane separately from natural gas. A rule would be needed to specify that all Title 24 analysis must be done assuming natural gas, unless natural gas is not available in the street adjacent to the site; in which case the Title 24 analysis would assume propane as the fuel for heating and water heating.

Residential Alternative Component Packages would need to include a line under space-heating system to cover the efficiency requirement “If propane”. Language may be needed to clarify that the Standards’ use of the term “gas” refers to “natural gas”, not “propane gas”.

Other changes to the Standards associated with the TDV engineering enhancements will be addressed in the separate reports prepared for each of those enhancements.

Proposed ACM Language

For the residential ACM, the TDV economics proposal would result in the following changes:

1. Section 1.3 Application Checklist would need a new section requiring “TDV Factor Documentation” to demonstrate that the ACM is applying the hourly values correctly. In addition, the requirement for Weather Data Documentation when ACMs use part year weather data would be dropped. Part year simulation analysis would no longer be allowed.

2. Rules would be inserted to specify how the hourly TDV factors are multiplied by the hourly energy usage values for the standard design and the proposed design modeling outputs.

3. The standard compliance forms would need minor adjustments to reflect the new TDV energy which would replace source energy.

4. Rules for when and how to assume propane as the heating fuel in lieu of natural gas would need to be inserted.

For the nonresidential ACM, the TDV economics proposal would result in the following changes:

1. Section 1.1 Application Checklist would need a new section requiring "TDV Factor Documentation" to demonstrate that the ACM is applying the hourly values correctly. In addition, the requirement for Weather Data Documentation when ACMs use part year weather data would be dropped. Part year simulation analysis would no longer be allowed.

2. A new section 2.1.6 Time Dependent Valuation would be inserted between the existing sections 2.1.5 Reference Year and 2.1.6 Output Reports. This new section would say:

   "The program must the hourly energy use modeled for both the reference design and the proposed design by the hourly TDV factor for each hour of the reference year. TDV factors have been established by the CEC for residential and nonresidential occupancies, for each of the sixteen climate zones, and for each fuel (electricity, natural gas and propane). The hourly TDV values are published in the computer file XXXXX."

3. In addition, the analysis rules would need adjustments to allow for the default fuel (natural gas) to be replaced with propane when natural gas is not available in the street adjacent to the site.

4. Standard performance output compliance forms would need minor modifications to indicate results based on TDV, and to distinguish propane versus natural gas.

Other changes to the ACMs associated with other TDV engineering enhancements will be addressed in the separate reports prepared for each of those enhancements.

Bibliography and Acknowledgements

Bibliography

Copies of each of these reports is available by request from the authors.

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Pacific Gas & Electric Company, by Heschong Mahone Group. *Time Dependent Valuation of Energy for Developing Building Efficiency Standards,* 2000.

Pacific Gas & Electric Company, by Heschong Mahone Group and Energy & Environmental Economics. *Time Dependent Valuation (TDV) Formulation 'Cookbook',* March 15, 2002.

Acknowledgements

The development of the Time Dependent Valuation economics methodology, and associated engineering enhancements, has been sponsored primarily by the Pacific Gas & Electric Company, lead by Gary Fernstrom and Patrick Eilert. Additional support in the development of TDV has come from the Southern California Gas Company, Lance DeLaura and A.Y.Ahmed; and from Southern California Edison Co., Gregg Ander and Tony Pierce.

The consultant team was lead by the Heschong Mahone Group, Douglas Mahone and Jon McHugh. The economics subcontractor was Energy and Environmental Economics, Brian Horii and Snuller Price. The engineering consultants were Charles Eley and Bruce Wilcox. Implementation support came from Ken Nittler and Martyn Dodd.

Throughout the development process, the staff of the California Energy Commission has reviewed and advised on the development of the TDV methodology. Key participants were William Pennington and Jon Leber.

Stakeholder advice has also been sought as the TDV proposal developed. We especially acknowledge the California Building Industries Association, with Bob Raymer and his consultants Mike Hodgson and Rob Hammon; and the Natural Resources Defense Council, Noah Horowitz and David Goldstein.

Appendices

The development of the Time Dependent Valuation economics methodology, and associated engineering enhancements, has been sponsored primarily by the Pacific Gas & Electric Company, lead by Gary Fernstrom and Patrick Eilert. Additional support in the development of TDV has come from the Southern California Gas Company, Lance DeLaura and A.Y.Ahmed; and from Southern California Edison Co., Gregg Ander and Tony Pierce.

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Appendix A - Conversion of TDV Dollars Into TDV Energy Units

TDV's are based on the present value of each hour's energy cost over the 15-year nonresidential analysis period and over the 30-year residential analysis period. Forecasts of commodity costs and rates over these time periods are used to calculate the future value of these costs and then these are assigned a present value by applying a 3% real (inflation adjusted) discount rate.

From a policy perspective it was considered desirable to normalize TDV's in terms of energy units instead of dollars for the following reasons:

- Describing TDV's in terms of energy units would maintain the units and the look of performance method compliance reports. It is felt that this would minimize the impact of TDV on practitioners - the proposed building would have to still use less energy than the reference building only in this case it is TDV energy rather than source energy.

- If PV (present valued) dollars were the units used, this would imply that the customer's savings should be equal to this amount over the period of analysis. Given that the TDV's are not the same as rates and that there are limitations to the ACM programs to predict any given year's consumption, it was not desirable to imply that the TDV savings are the same as the dollar savings that any single customer might realize.

Converting the TDV dollar values into nominal energy units followed the precedent of the source energy method. The base energy unit for the source method was a kBtu of natural gas. The base energy unit for TDV is the nominal cost of natural gas. This is the load weighted average cost of natural gas across the entire state for each customer class over the entire year.

Thus there is a nonresidential nominal gas cost and a residential nominal gas cost. The nonresidential nominal gas cost of PV$0.0745/kBtu is based on a 15 year forecast of natural gas costs for nonresidential customers and discounted into 2001 dollars. A similar residential nominal gas cost of PV$0.145/kBtu is based on a 30 year forecast for residential customers.

The TDV dollar values for electricity are given in terms of PV$/kWh for electricity, and PV$/therms for natural gas and propane. Dividing these TDV dollar values by the nominal value cost for natural gas results in TDV energy units of TDV kBtu/kWh for electricity and TDV kBtu/therm for natural gas and propane. The equations below provide the units analysis.

For electricity, the TDV energy factors are in terms of TDV kBtu per kWh of electricity:

$$\text{TDV energy factors} = \frac{\text{TDV Dollars}\left[\text{PV\$/kWh}\right]}{\text{Nominal Cost}\left[\text{PV\$/TDV kBtu}\right]} = \frac{\dfrac{\text{PV\$}}{\text{kWh}}}{\dfrac{\text{PV\$}}{\text{TDV kBtu}}} = \frac{\text{TDV kBtu}}{\text{kWh}}$$

Just like TDV dollar values, the TDV energy factors vary for each hour of the year. To evaluate the TDV valuation of a measure each hour's electricity savings is multiplied by that hour's TDV energy value. As shown below, this yields an annual savings figure in terms of TDV kBtu.

$$\text{Annual TDV Savings}\left[\text{TDV kBtu}\right] = \sum_{h=1}^{8,760} \text{Energy Savings}_h\ \left[\text{kWh}\right] \times \text{TDV Energy Factor}_h \left[\frac{\text{TDV kBtu}}{\text{kWh}}\right]$$

For evaluating the cost-effectiveness of new measures, the annual TDV energy savings can be multiplied by the following nominal gas costs in PV $/kBtu $2001.

Residential (30 year) = PV$0.145/kBtu

Nonresidential (15 year) = PV$0.0745/kBtu

Nonresidential (30 year) = PV$0.129/kBtu

Note that there is a 15 year and a 30 year value for nonresidential measures. For the 2005 standards, the cost-effectiveness of nonresidential envelope measures will be evaluated based upon 30-year life cycle cost. All other nonresidential measures will be evaluated over 15 years.

A separate set of TDV energy factors was created to evaluate the TDV value of measures when air emission externalities are also accounted for. To convert these energy units in to present valued year 2001 dollars, multiply the energy TDV's by the following the following nominal gas costs in PV $/kBtu $2001.

Residential with air emission externalities (30 year) = $0.157/kBtu

Nonresidential with air emission externalities (15 year) = $0.0819/kBtu

Nonresidential with air emission externalities (30 year) = $0.141/kBtu

Appendix B – Residential Analysis Graphs

For a discussion of how to read these graphs, see the discussion above under Residential Analysis Graphs.

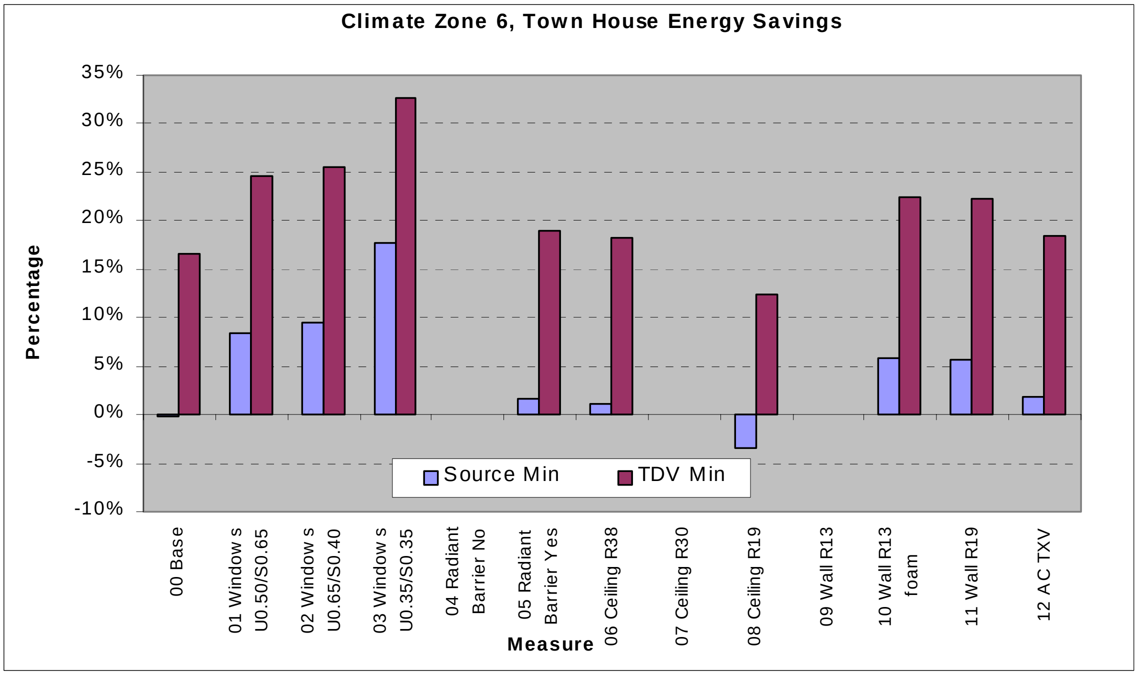

Figure D-1 - CTZ 6, Townhouse Parametrics, Part 1

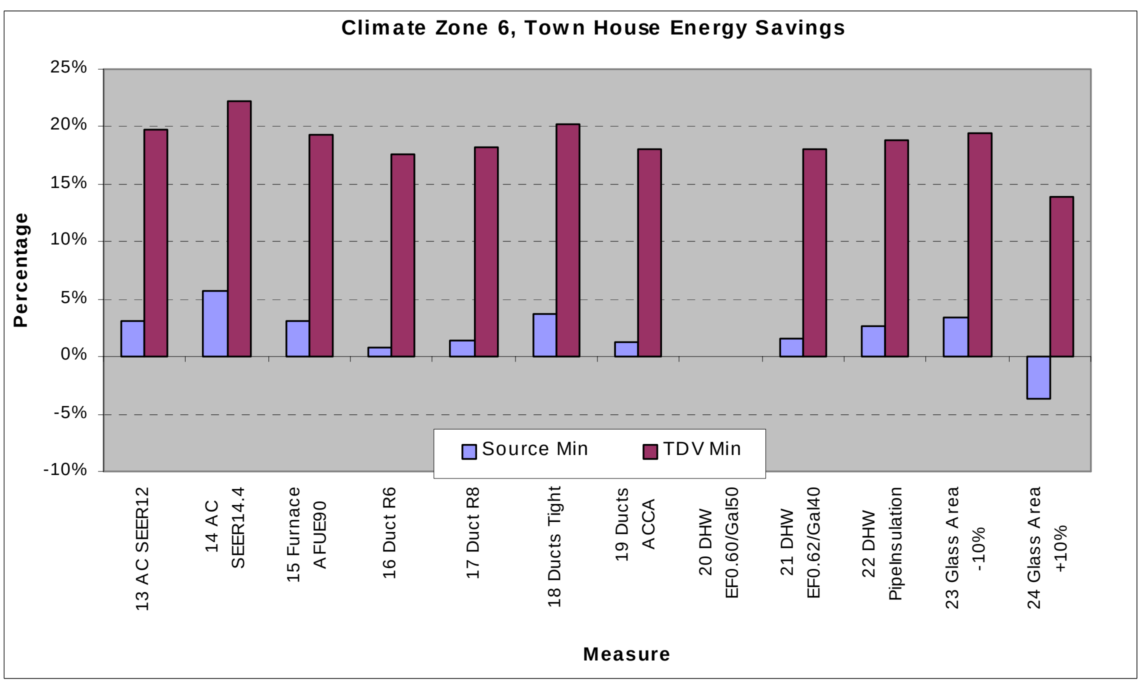

Figure D-2 - CTZ 6, Townhouse Parametrics, Part 2

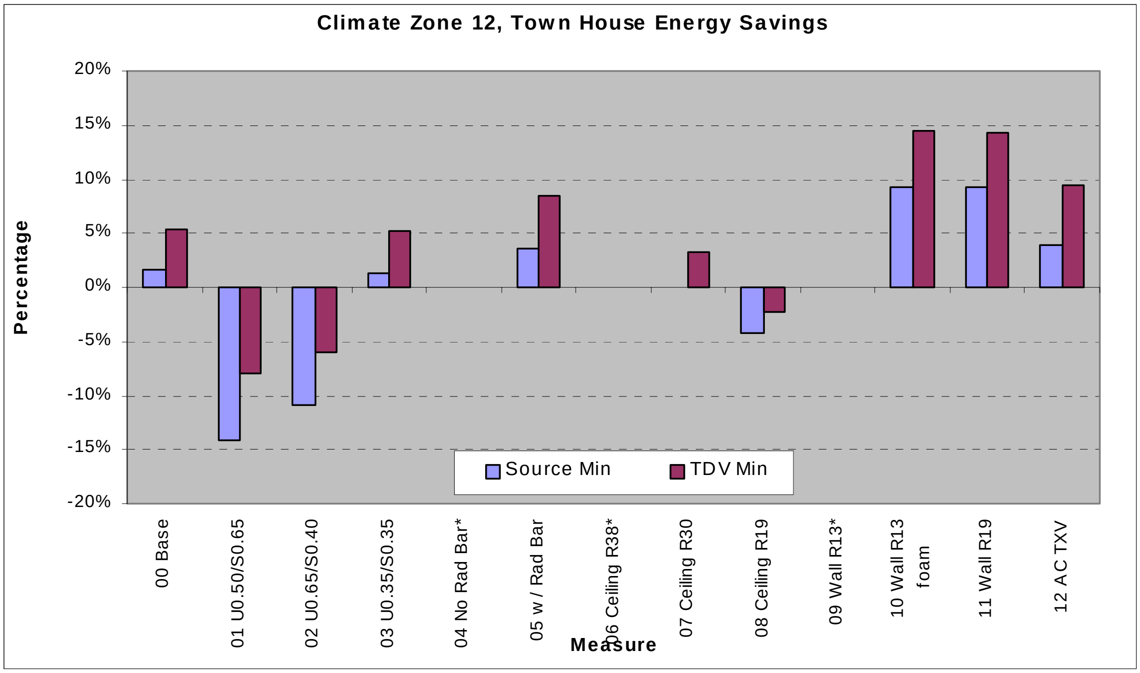

Figure D-3 - CTZ 12, Townhouse Parametrics, Part 1

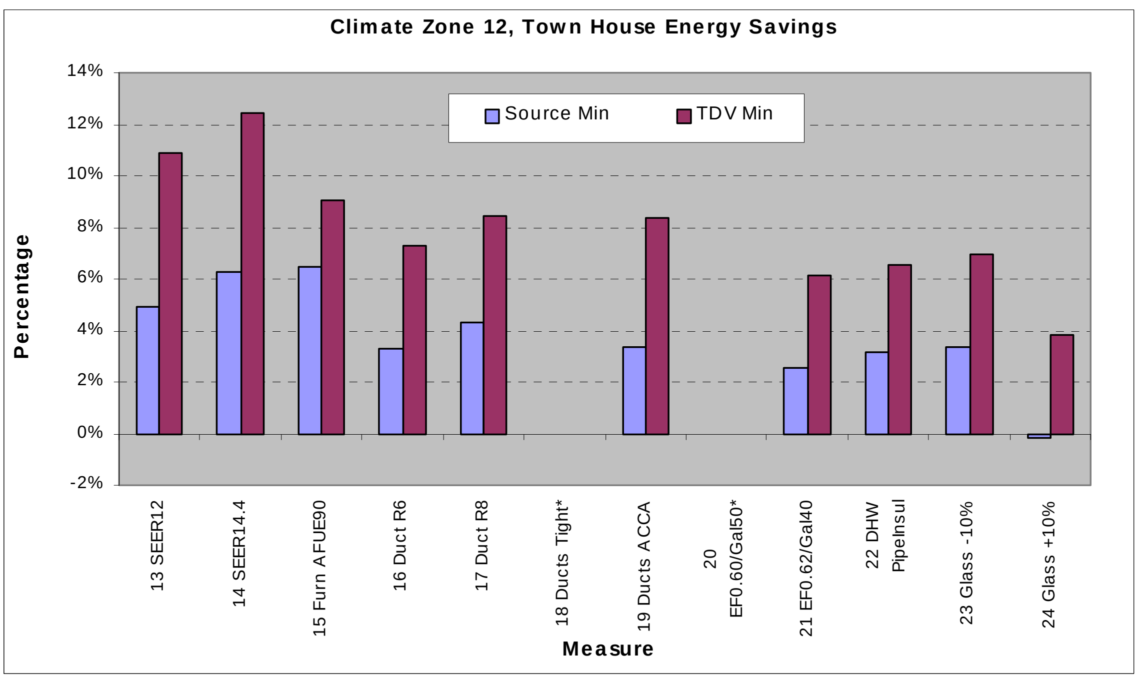

Figure D-4 - CTZ 12, Townhouse Parametrics, Part 2

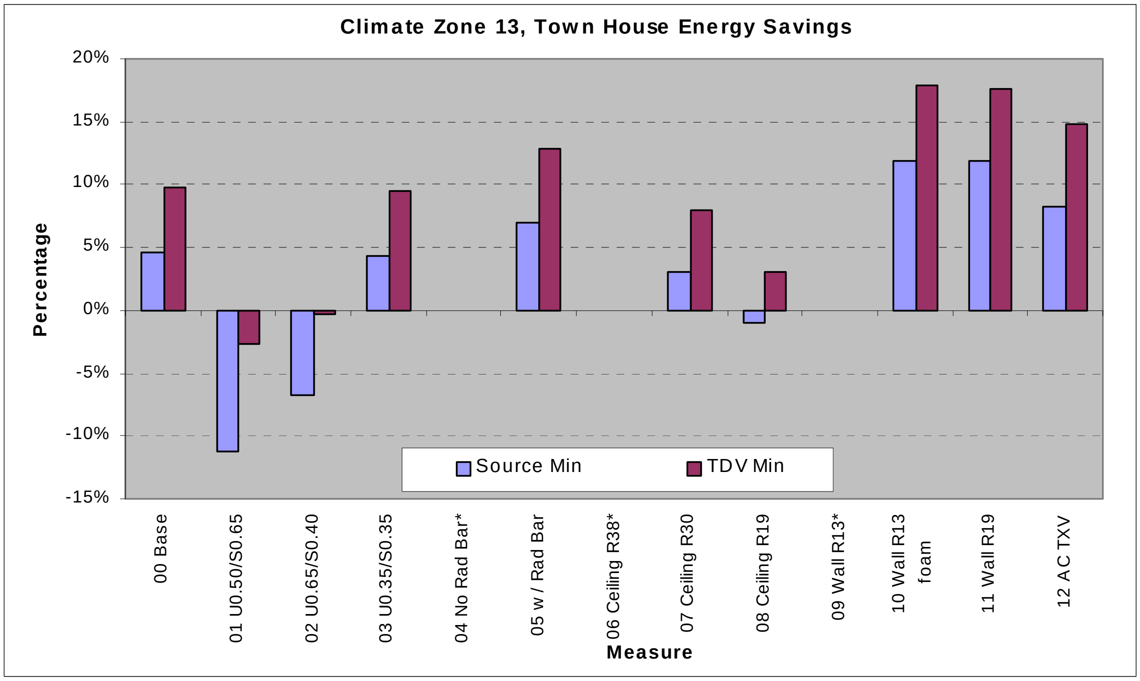

Figure D-5 - CTZ 13, Townhouse Parametrics, Part 1

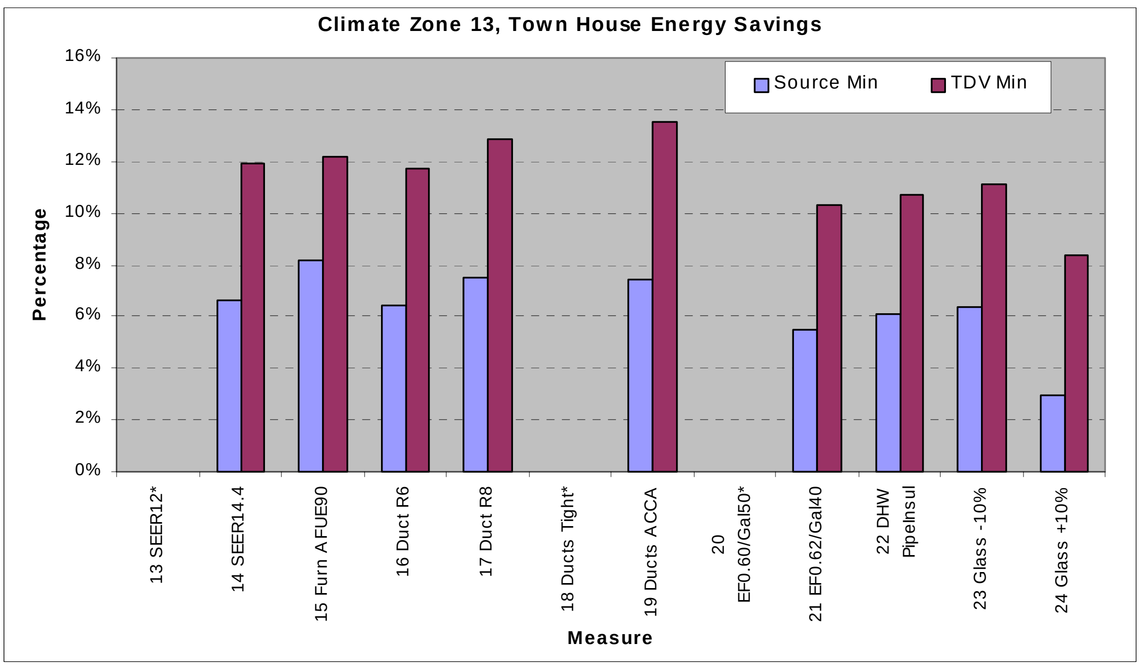

Figure D-6 - CTZ 13, Townhouse Parametrics, Part 2

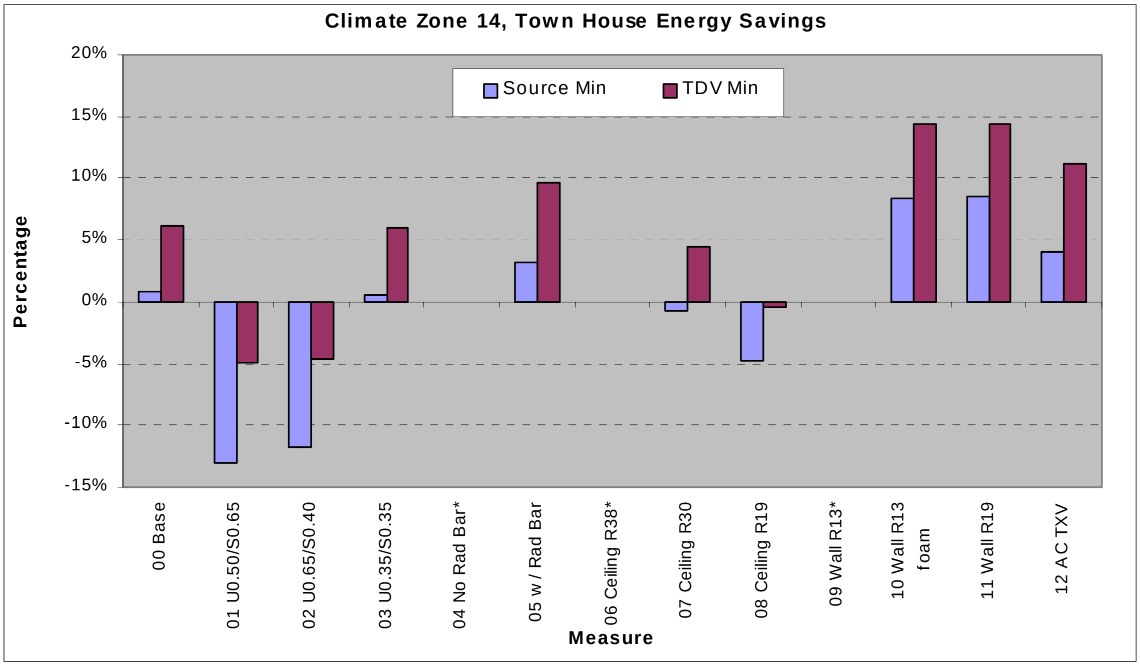

Figure D-7 - CTZ 14, Townhouse Parametrics, Part 1

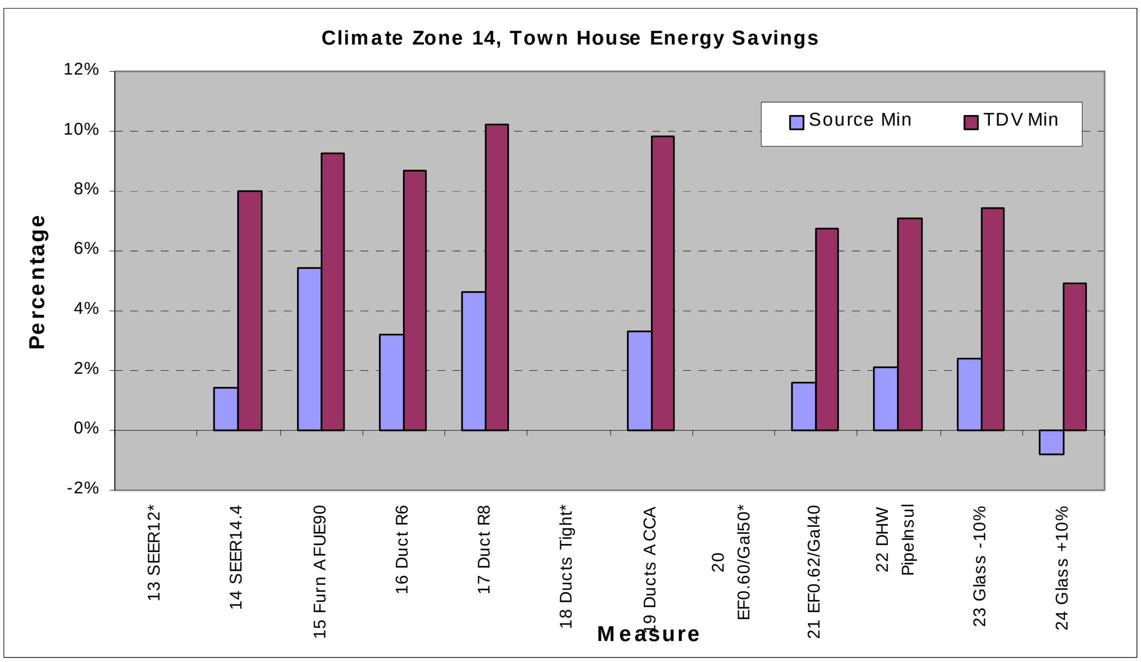

Figure D-8 - CTZ 14, Townhouse Parametrics, Part 2

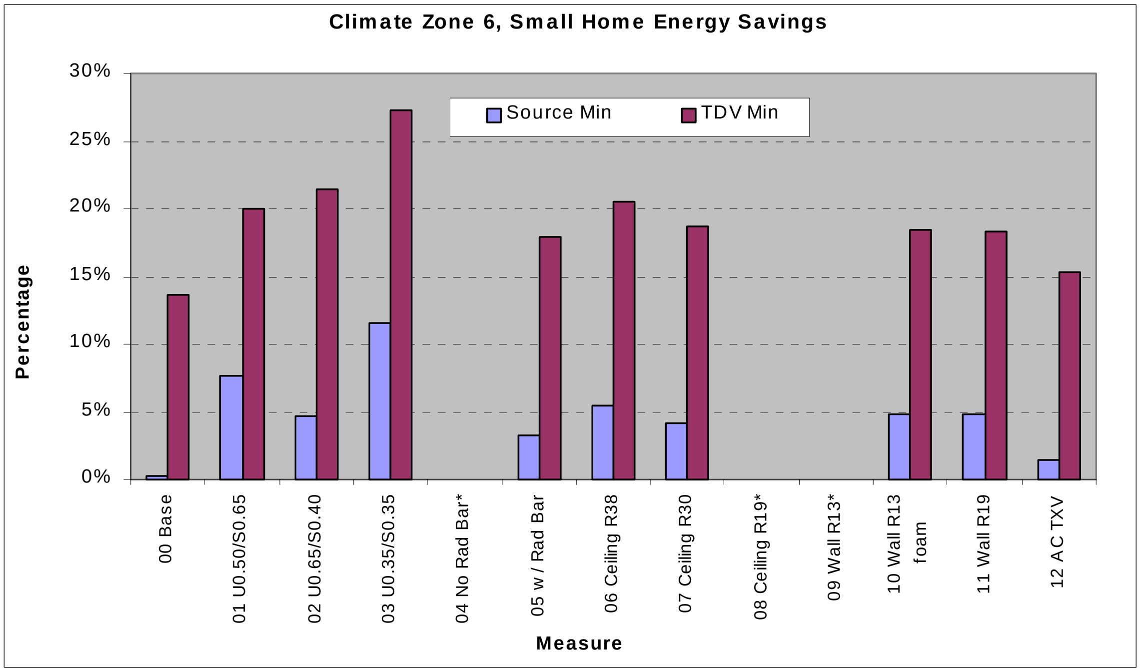

Figure D-9 - CTZ 6, Small Home Parametrics, Part 1

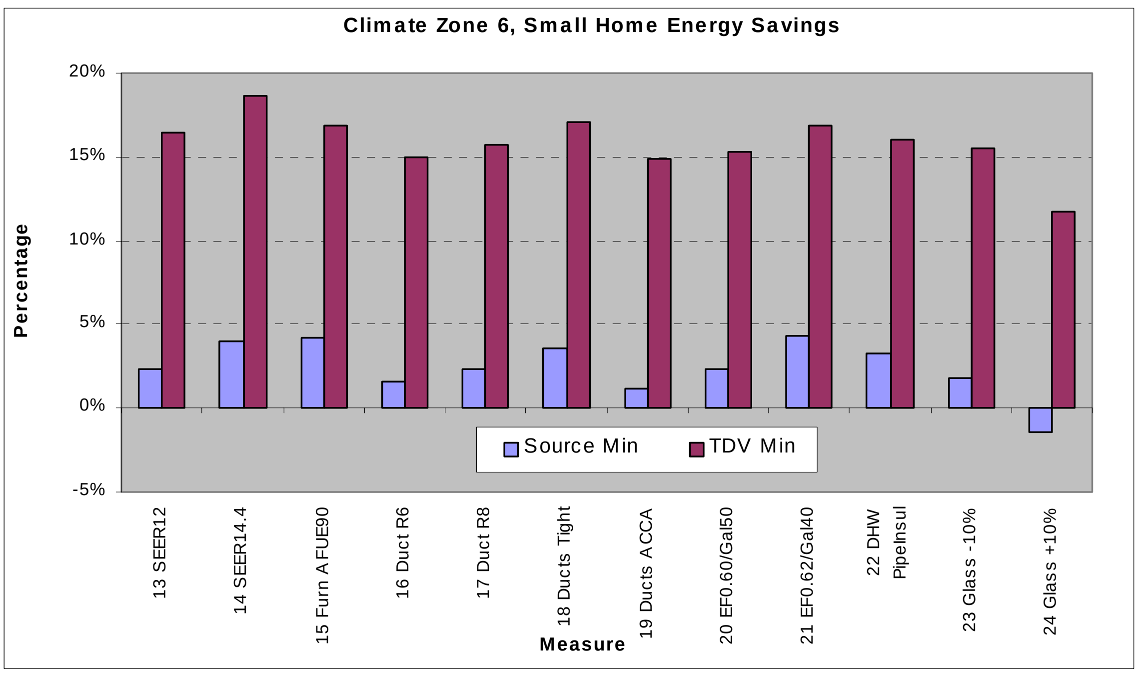

Figure D-10 - CTZ 6, Small Home Parametrics, Part 2

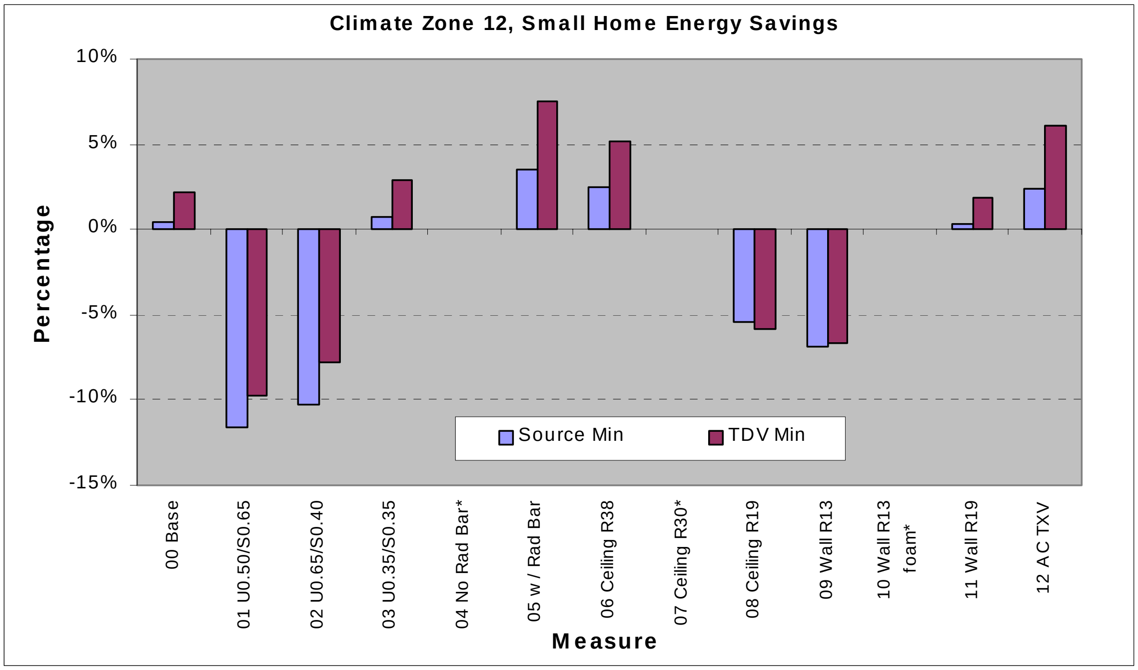

Figure D-11 - CTZ 12, Small Home Parametrics, Part 1

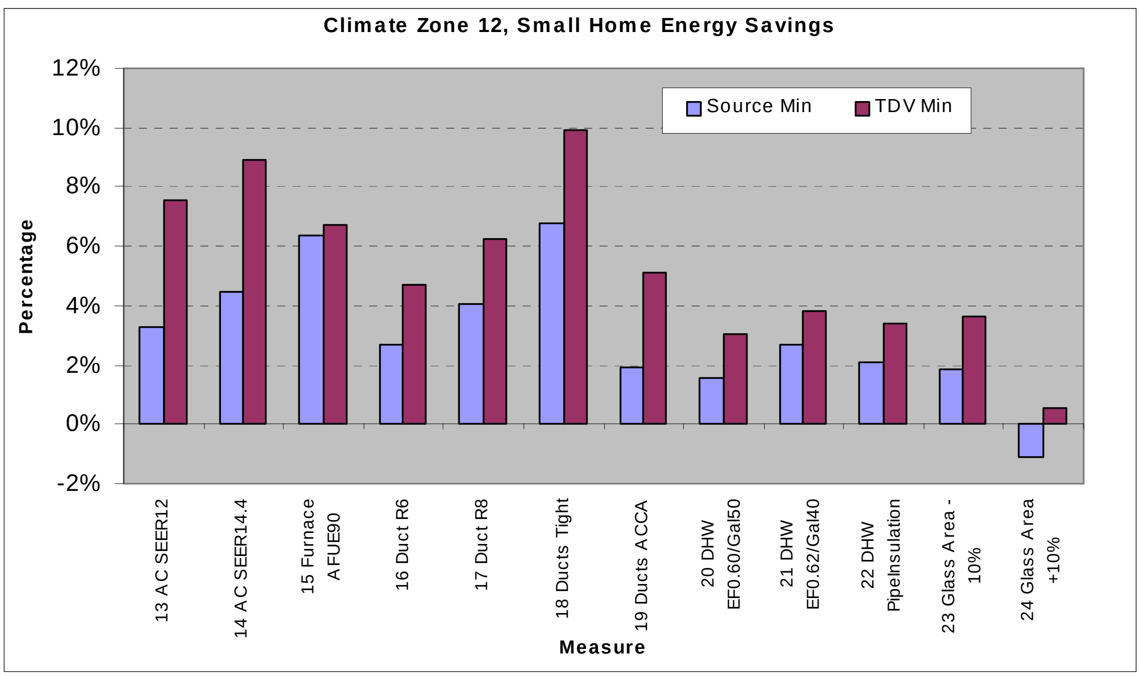

Figure D-12 - CTZ 12, Small Home Parametrics, Part 2

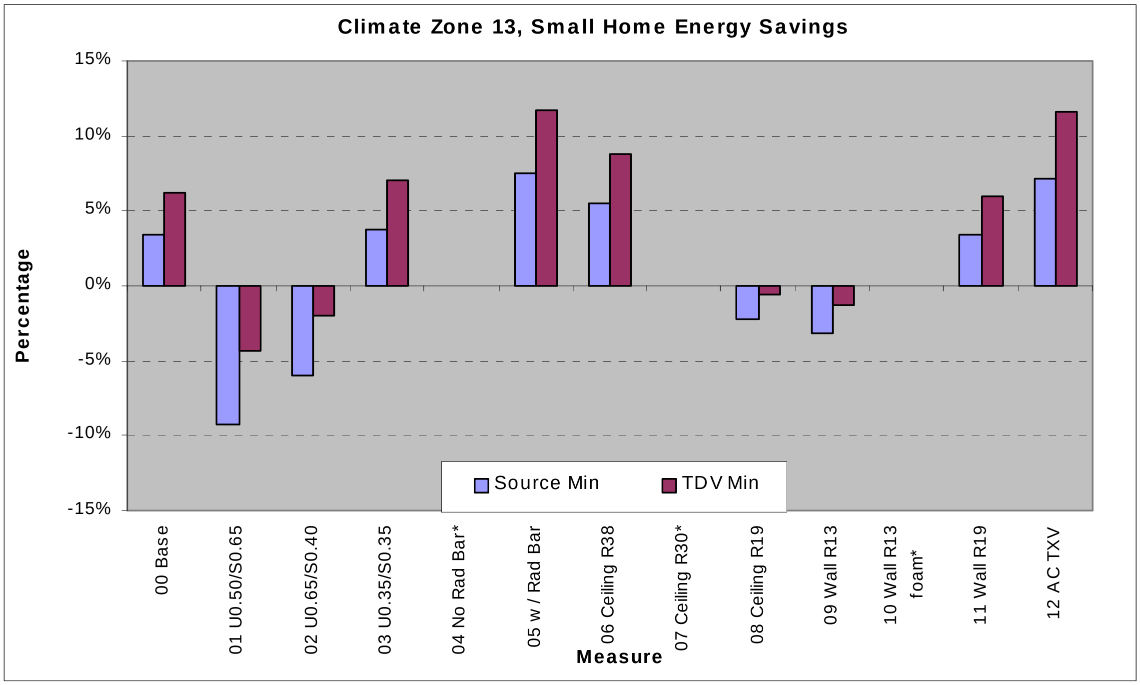

Figure D-13 - CTZ 13, Small Home Parametrics, Part 1

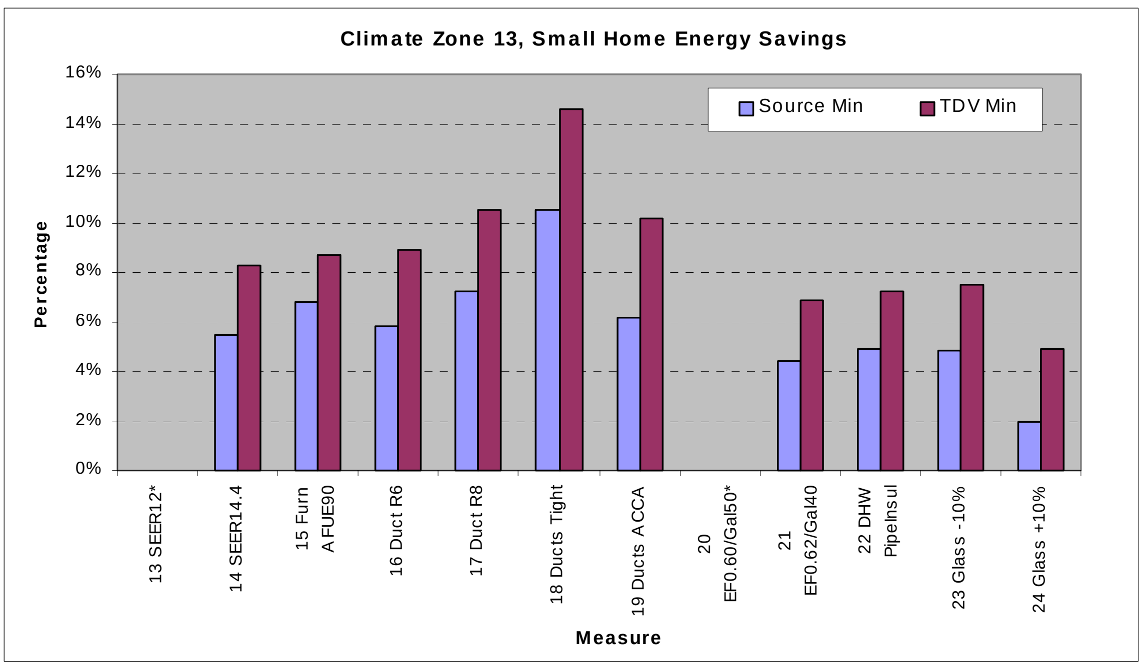

Figure D-14 - CTZ 13, Small Home Parametrics, Part 2

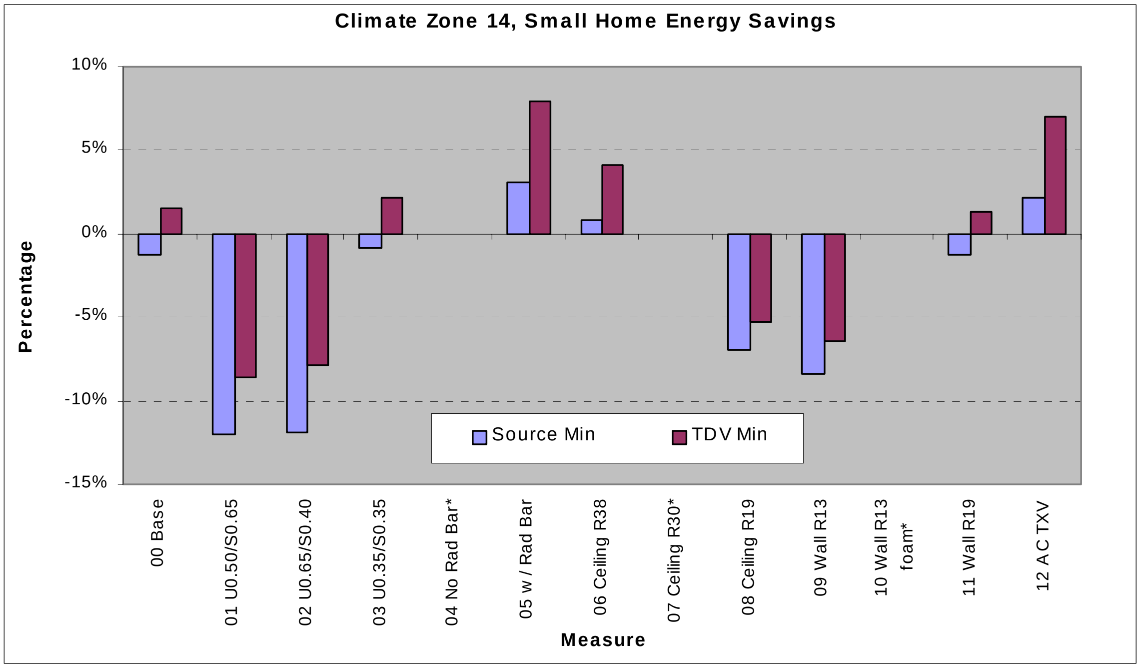

Figure D-15 - CTZ 14, Small Home Parametrics, Part 1

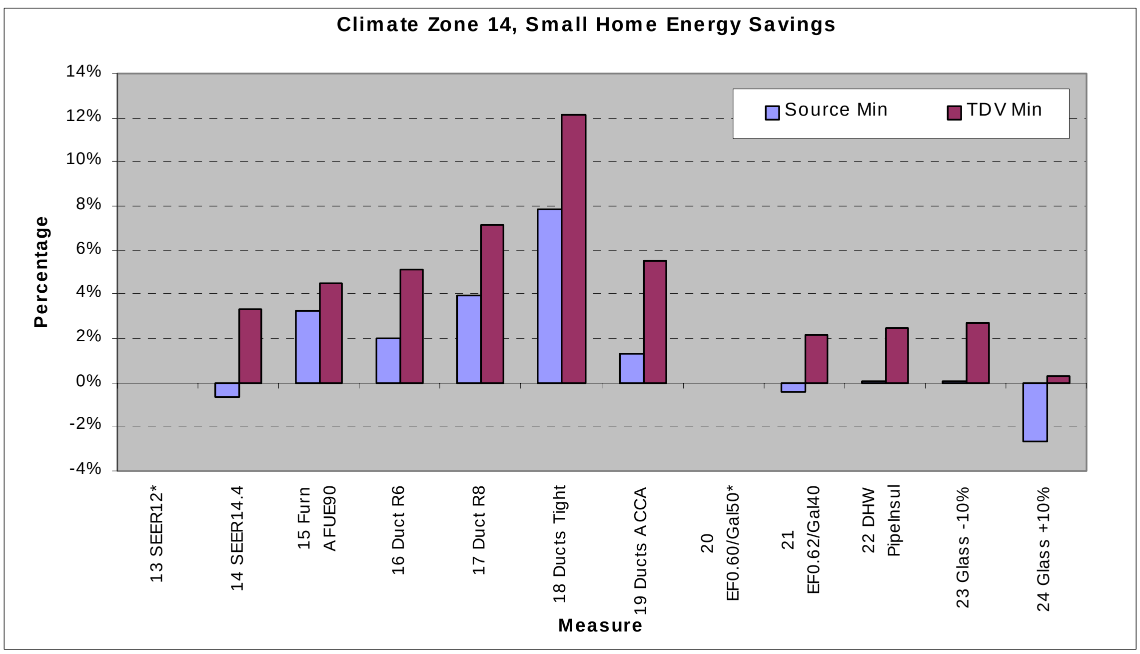

Figure D-16 - CTZ 14, Small Home Parametrics, Part 2

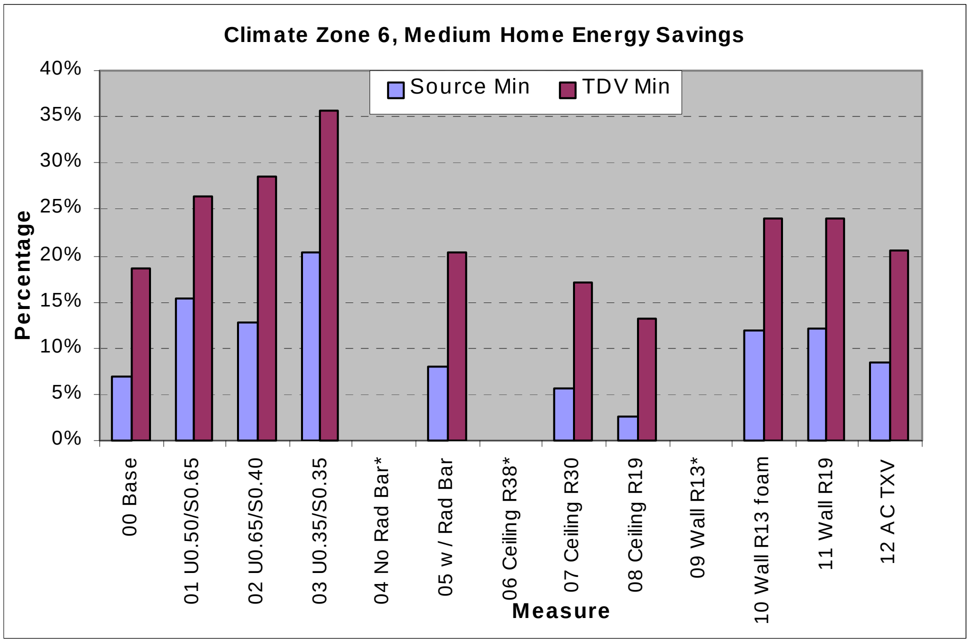

Figure D-17 - CTZ 6, Medium Home Parametrics, Part 1

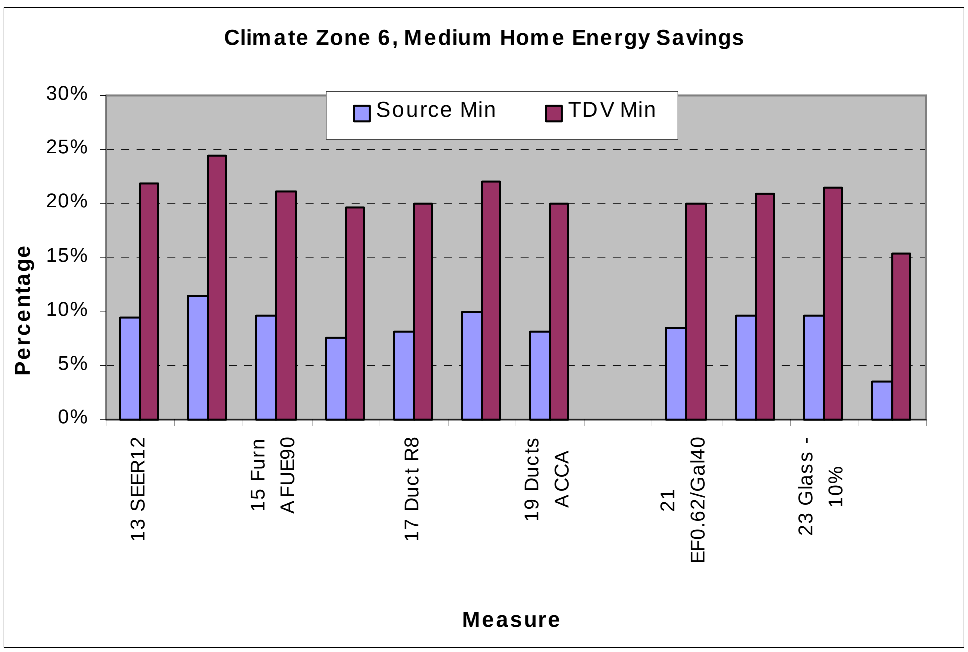

Figure D-18 - CTZ 6, Medium Home Parametrics, Part 2

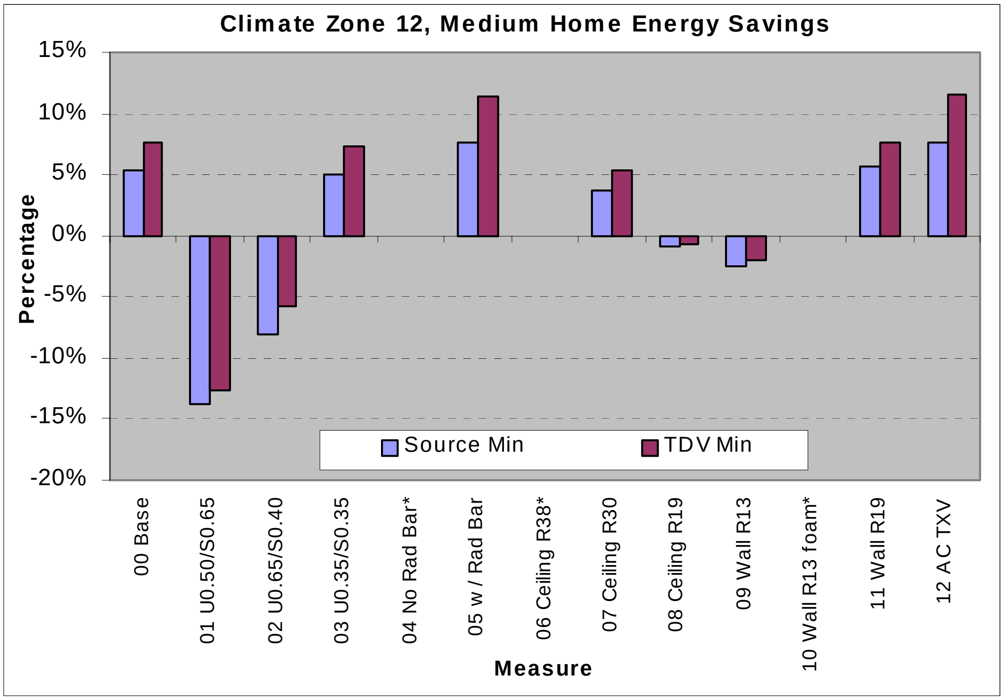

Figure D-19 - CTZ 12, Medium Home Parametrics, Part 1

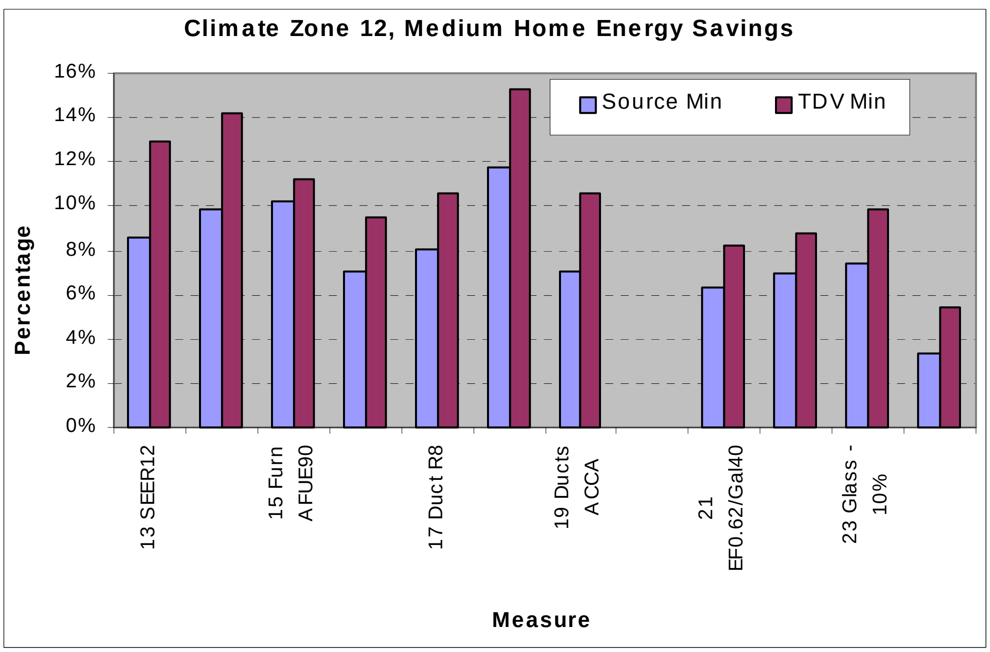

Figure D-20 - CTZ 12, Medium Home Parametrics, Part 2

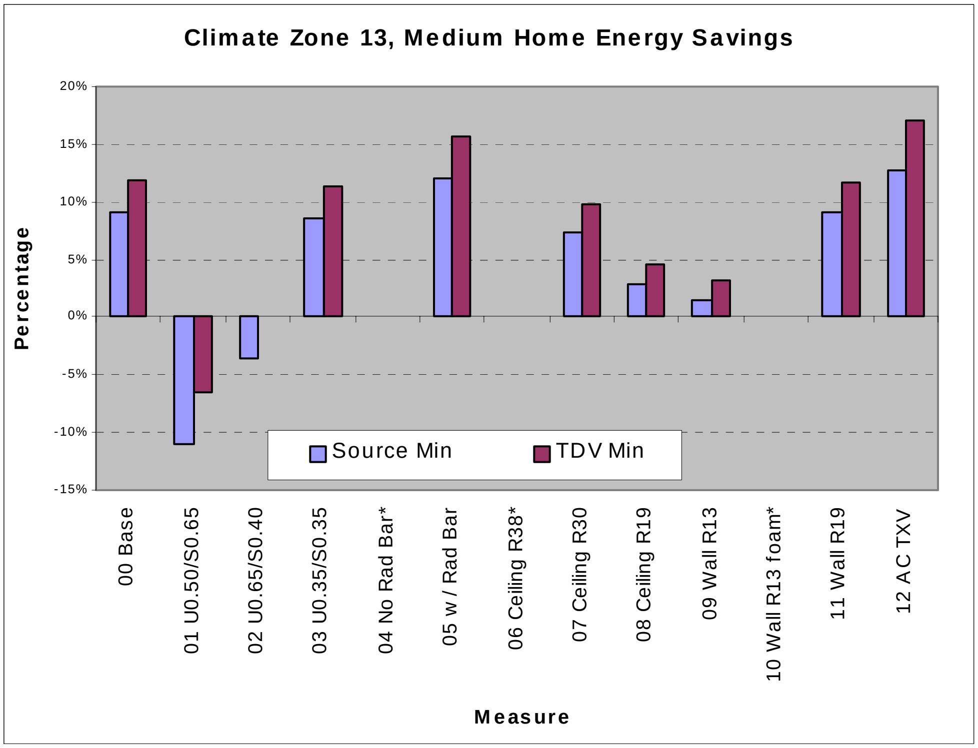

Figure D-21 - CTZ 13, Medium Home Parametrics, Part 1

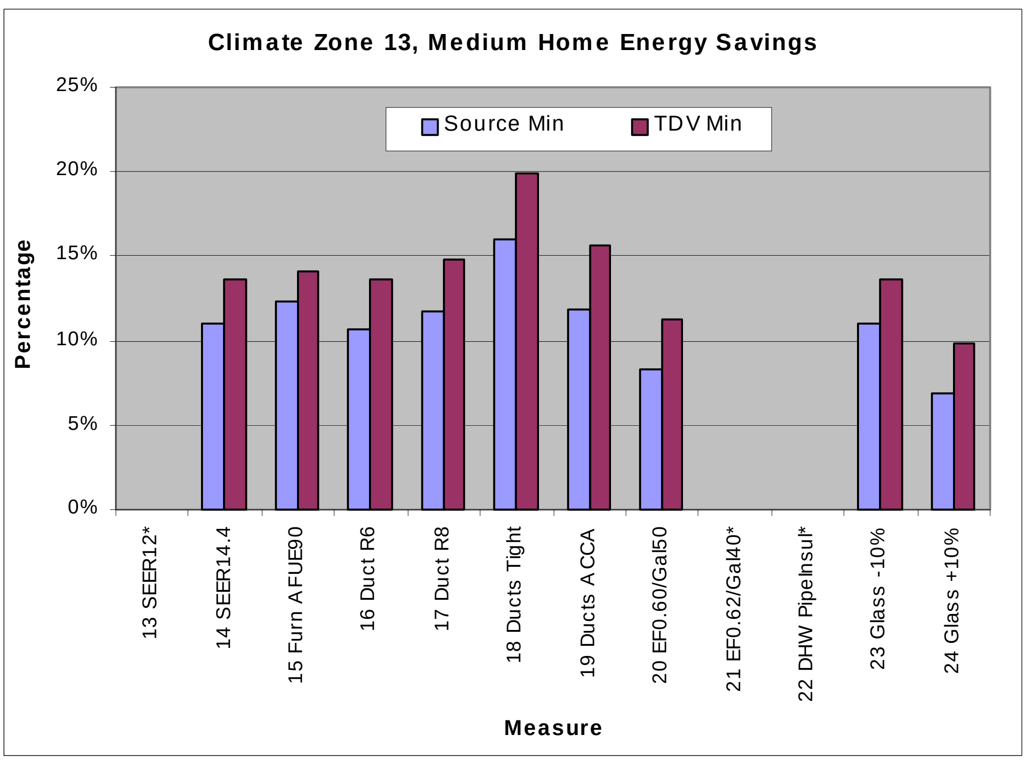

Figure D-22 - CTZ 13, Medium Home Parametrics, Part 2

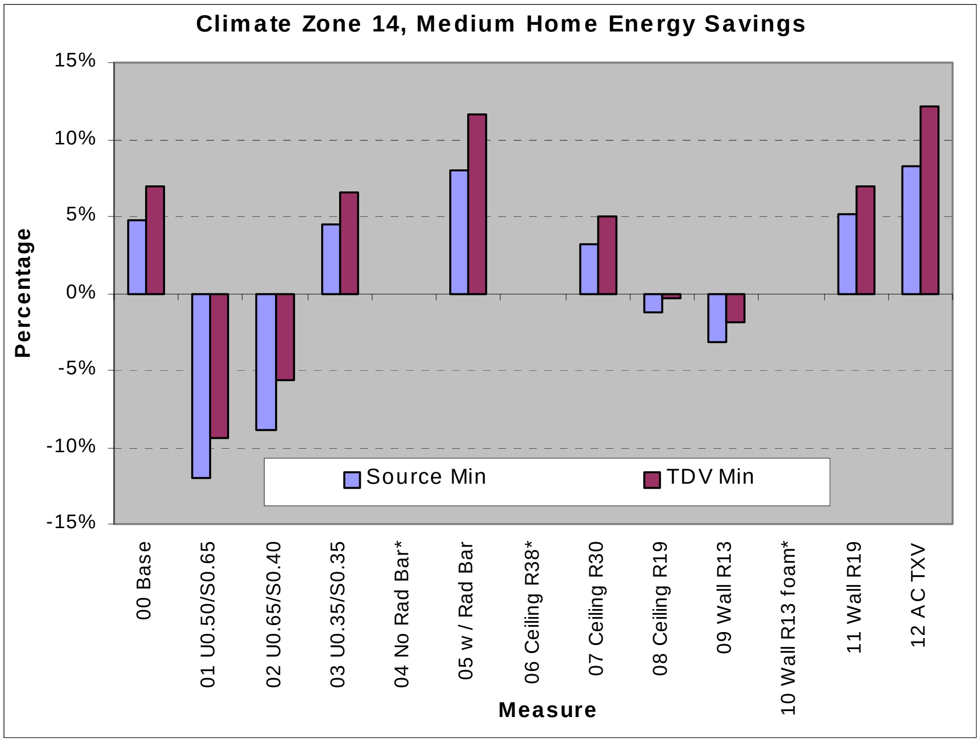

Figure D-23 - CTZ 14, Medium Home Parametrics, Part 1

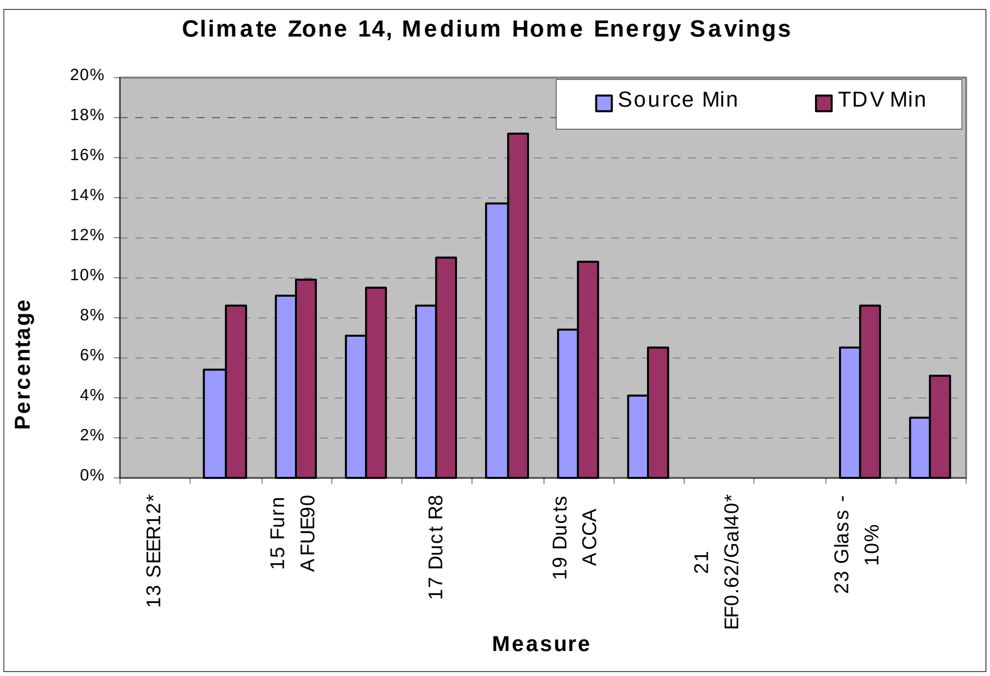

Figure D-24 - CTZ 14, Medium Home Parametrics, Part 2

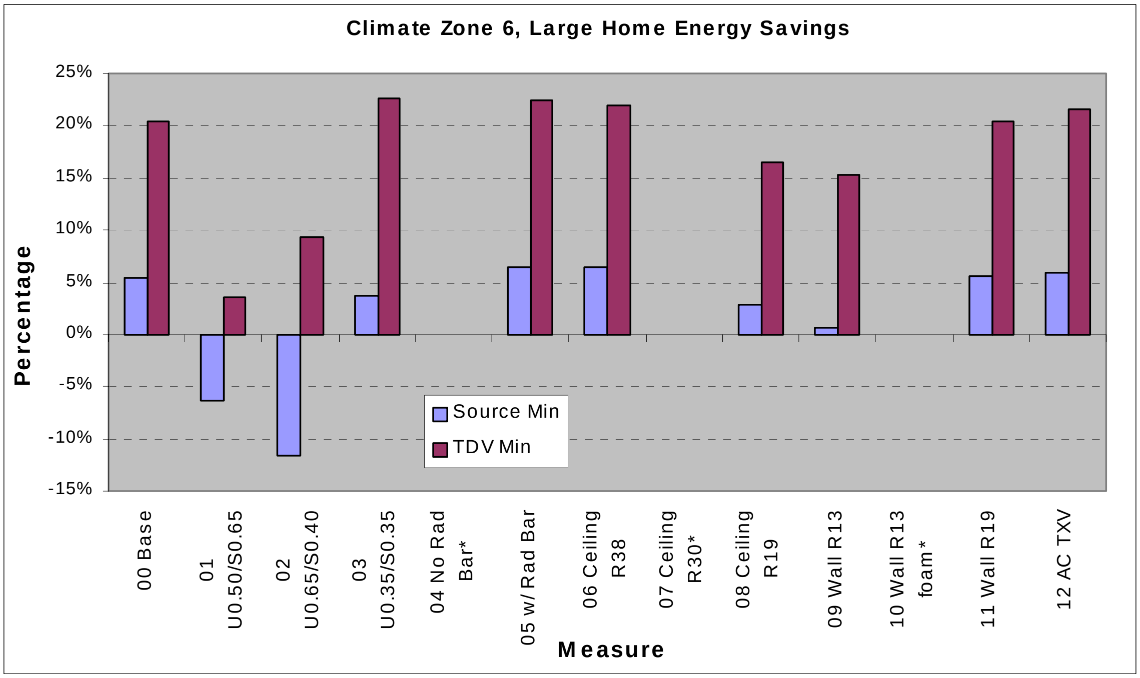

Figure D-25 - CTZ 6, Large Home Parametrics, Part 1

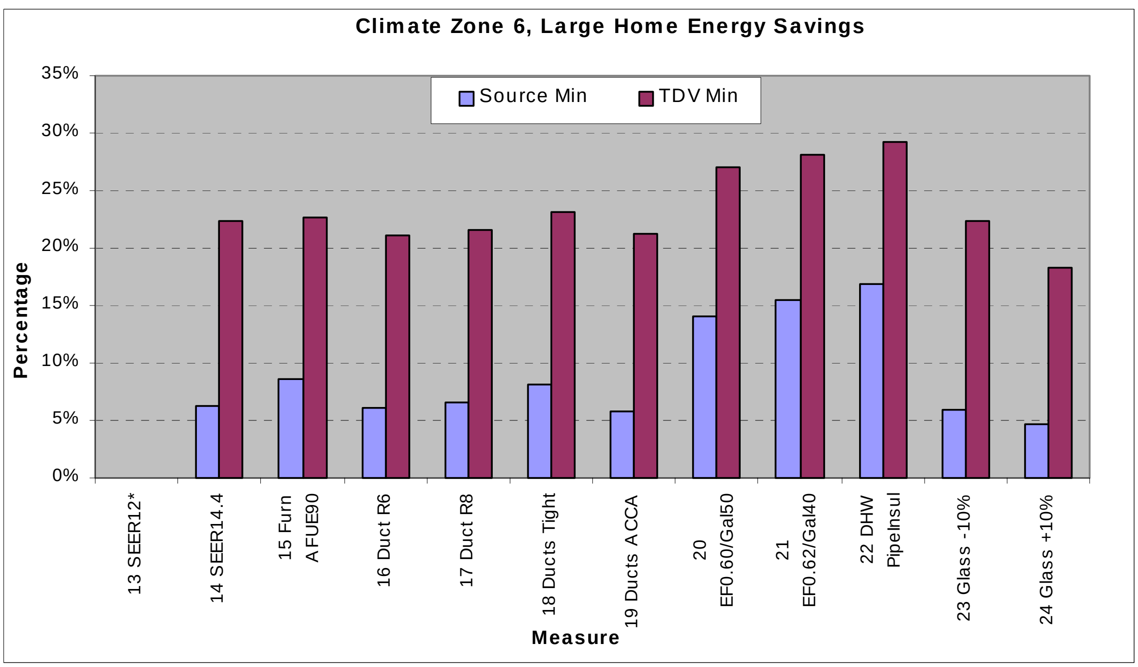

Figure D-26 - CTZ 6, Large Home Parametrics, Part 2

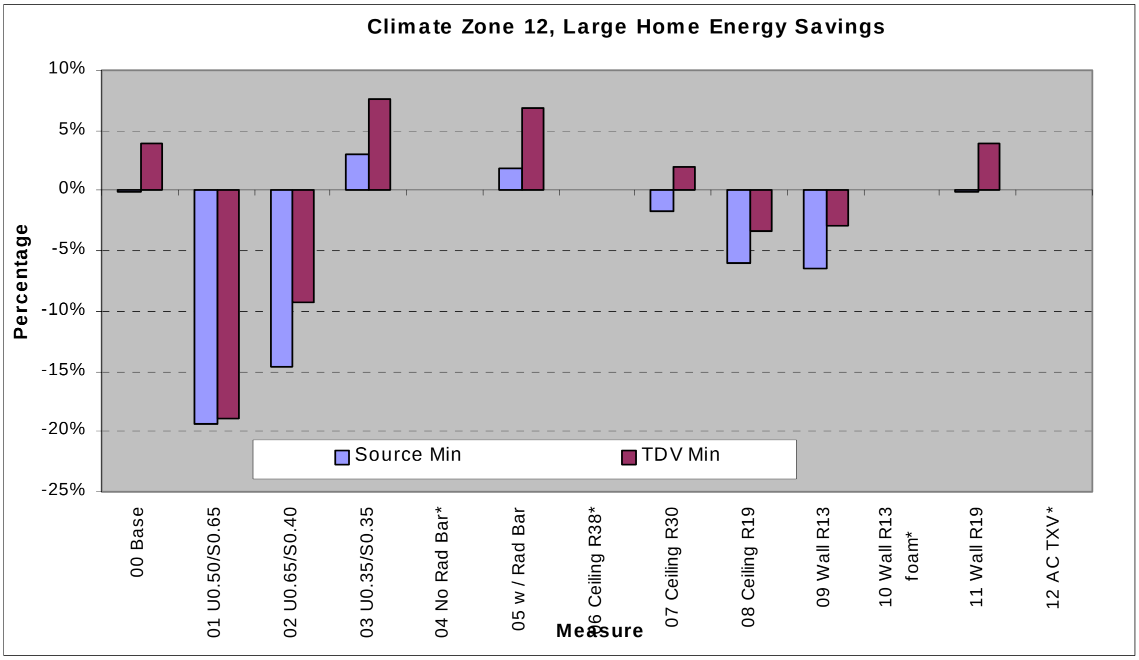

Figure D-27 - CTZ 12, Large Home Parametrics, Part 1

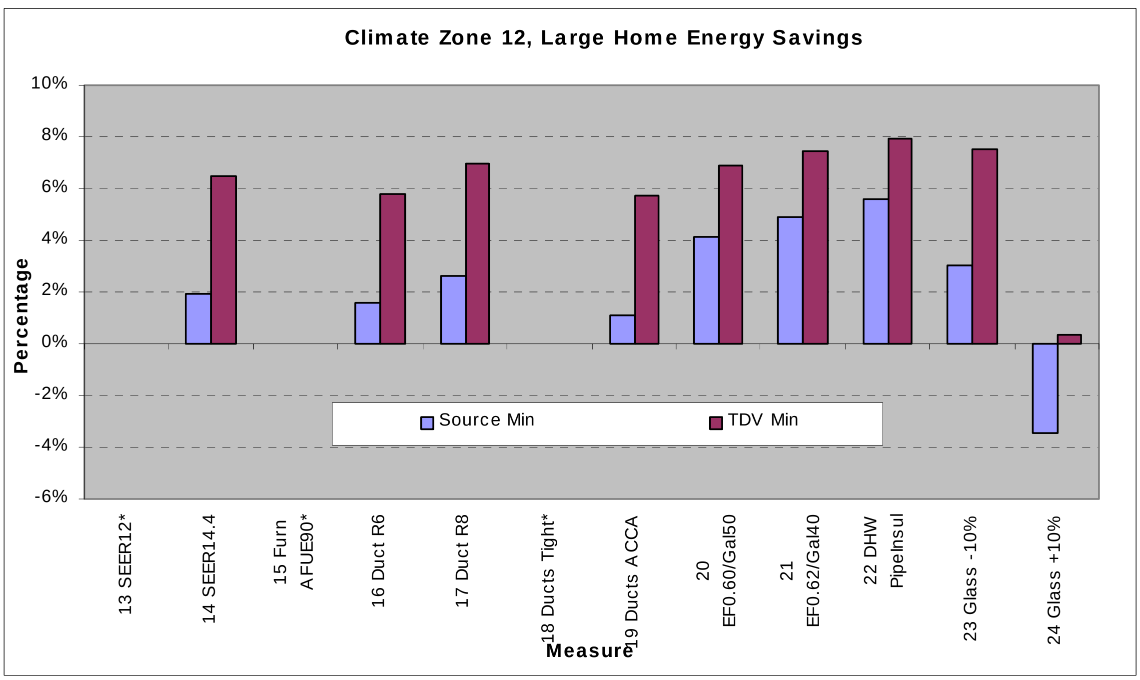

Figure D-28 - CTZ 12, Large Home Parametrics, Part 2

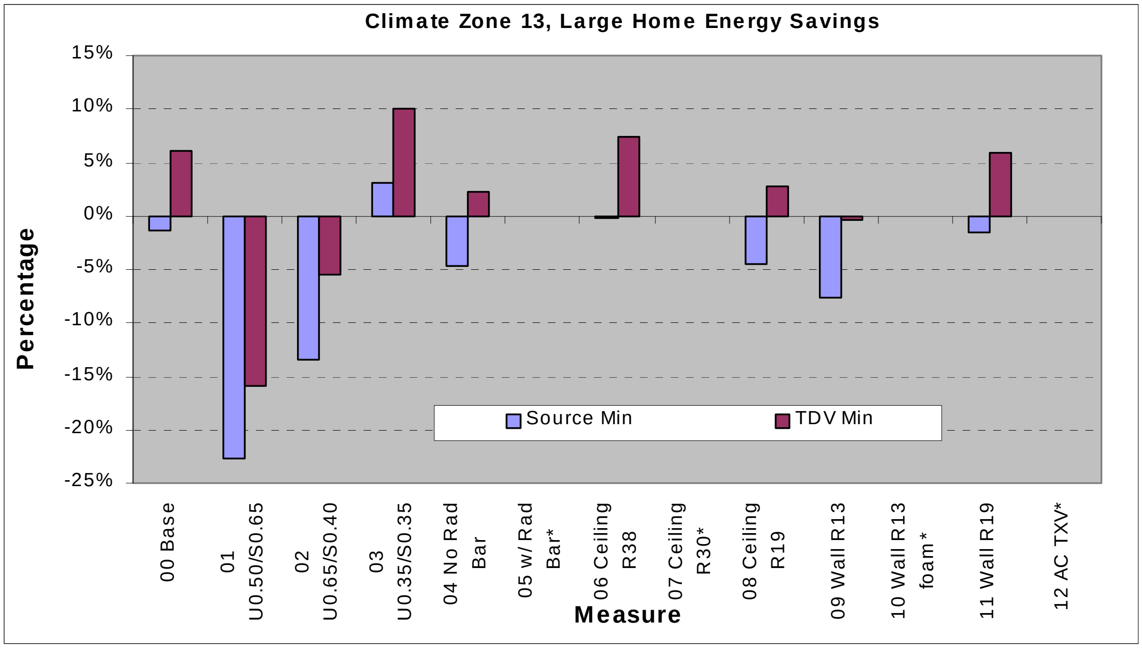

Figure D-29 - CTZ 13, Large Home Parametrics, Part 1

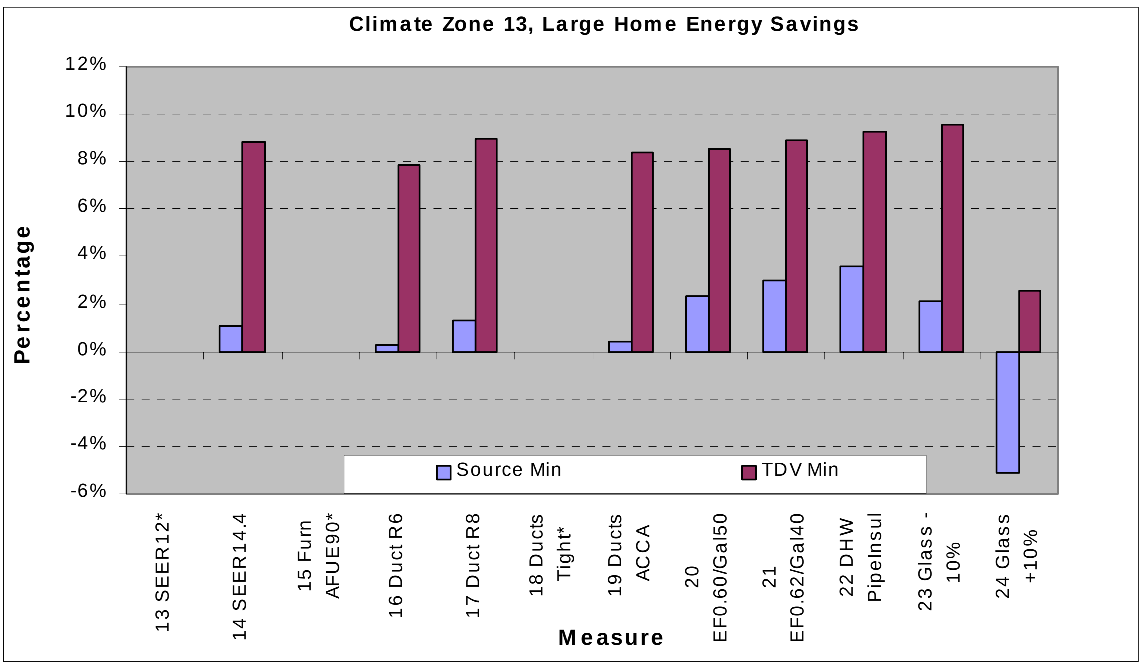

Figure D-30 - CTZ 13, Large Home Parametrics, Part 2

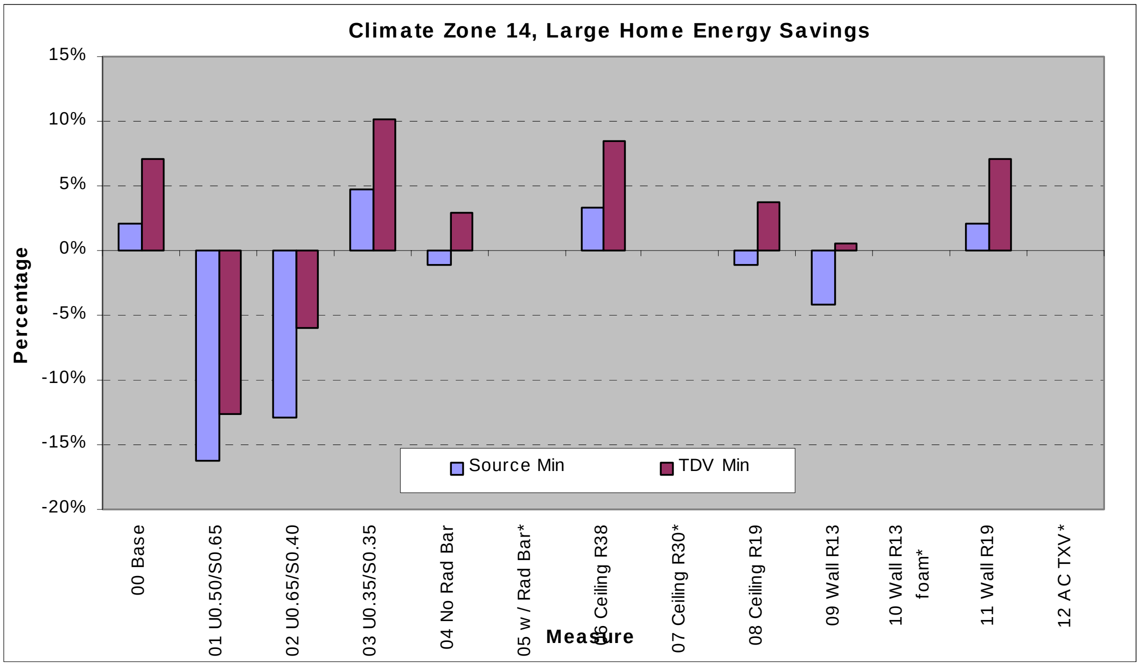

Figure D-31 - CTZ 14, Large Home Parametrics, Part 1

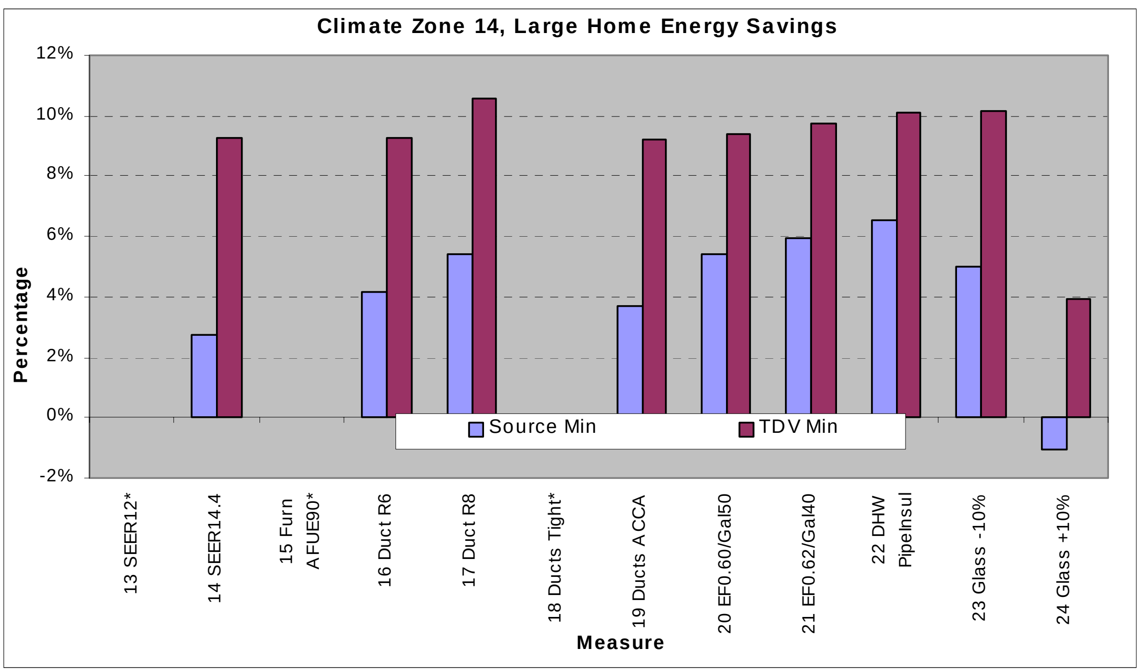

Figure D-32 - CTZ 14, Large Home Parametrics, Part 2

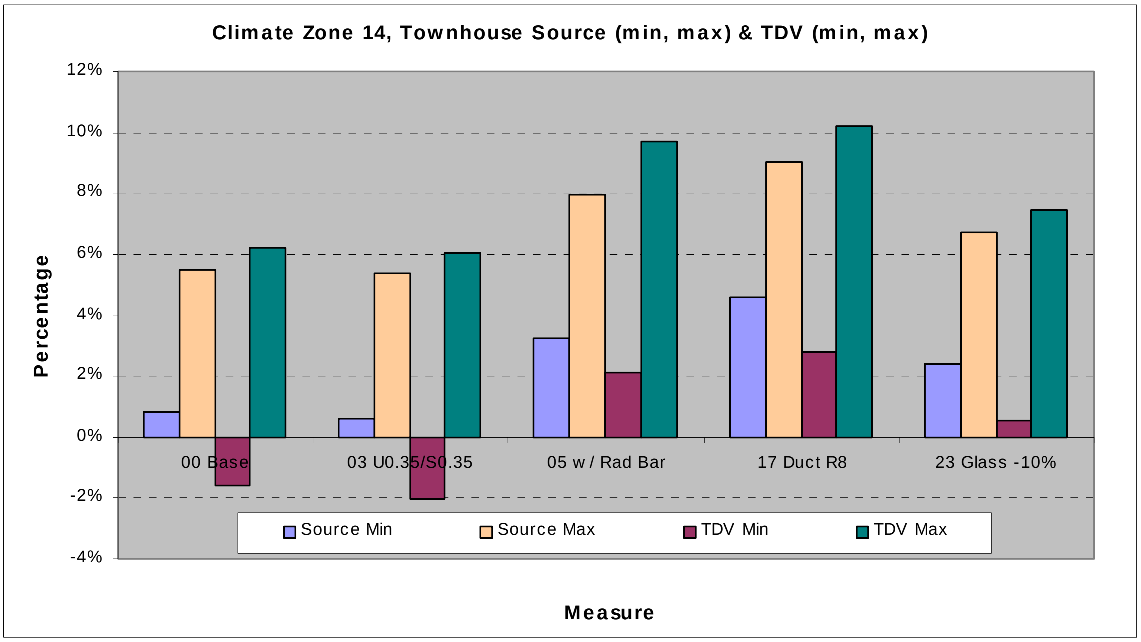

Figure D-33 - CTZ 14, Townhouse Min/Max Source/TDV Comparison

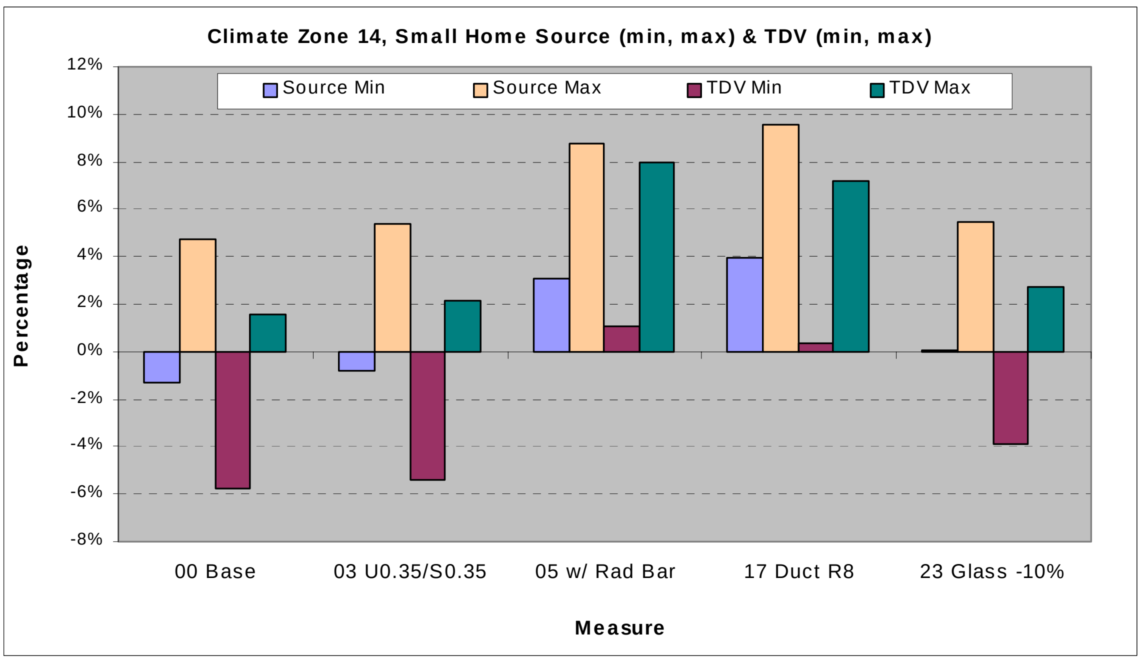

Figure D-34 - CTZ 14, Small Home Min/Max Source/TDV Comparison

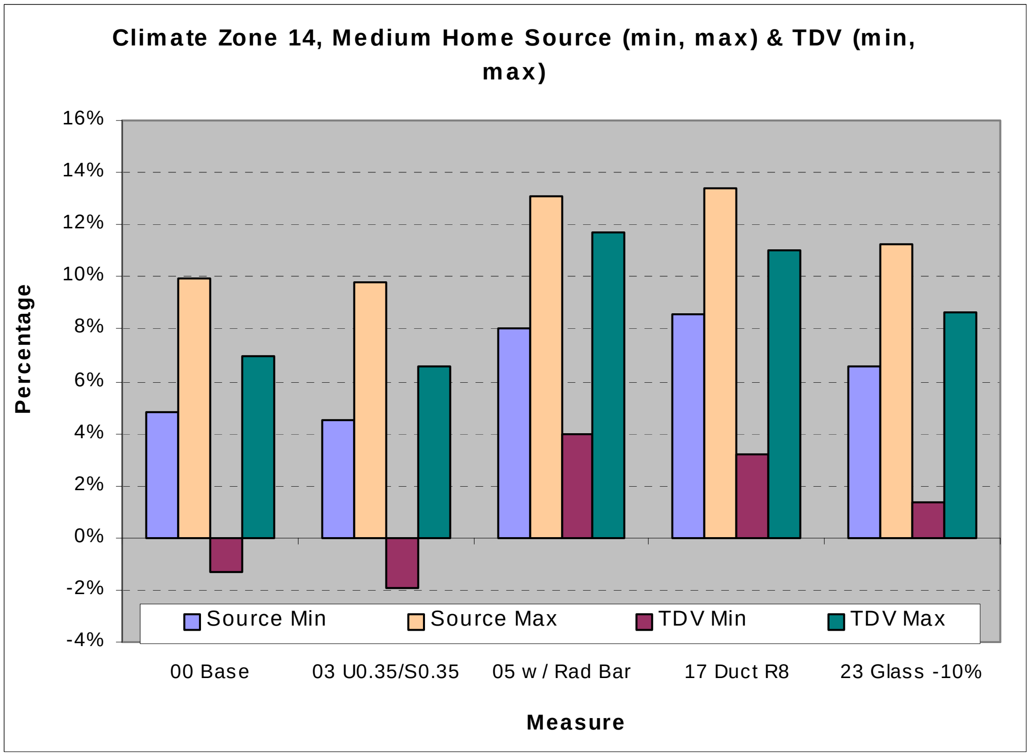

Figure D-35 - CTZ 14, Medium Home Min/Max Source/TDV Comparison

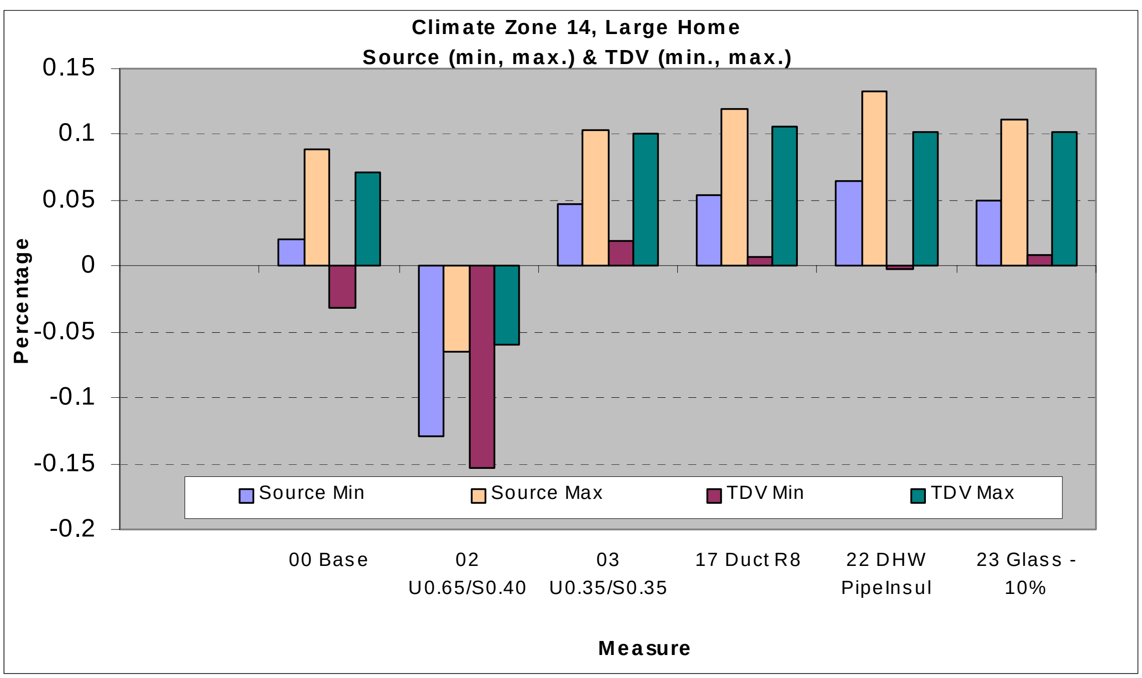

Figure D-36 - CTZ 14, Large Home Min/Max Source/TDV Comparison

Appendix C – Nonresidential Graphs

For information on how to read these graphs, see the discussion above under Nonresidential Analysis Results.

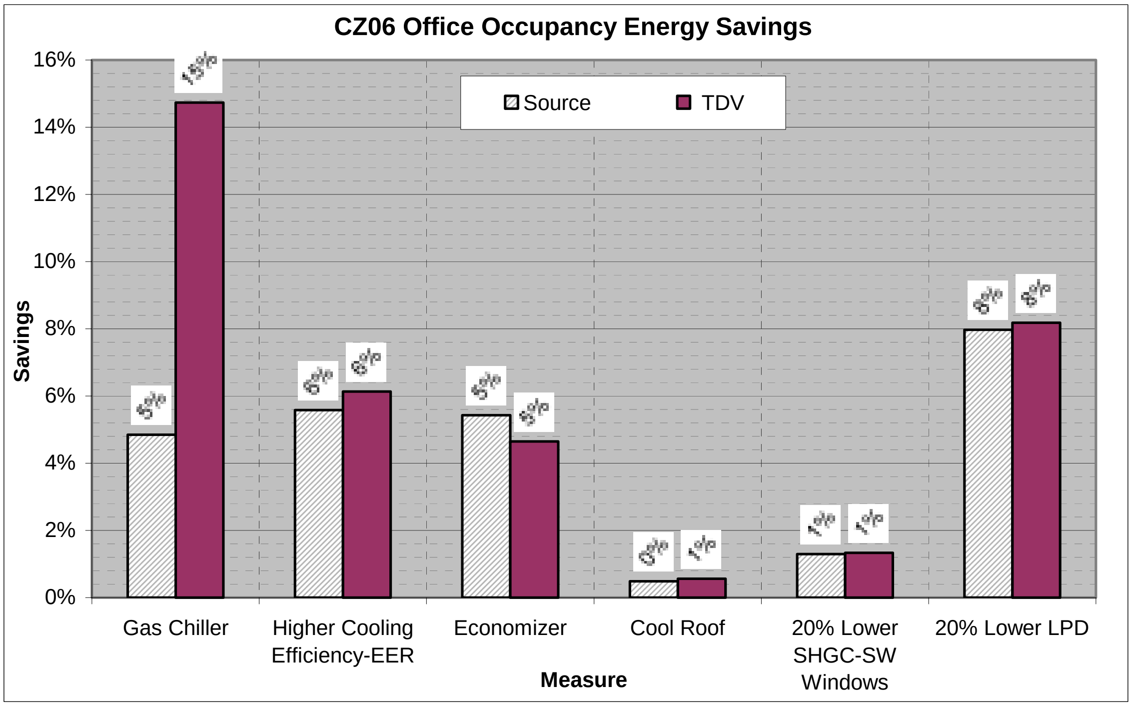

Figure E-1 - CTZ 6 Office Parametrics

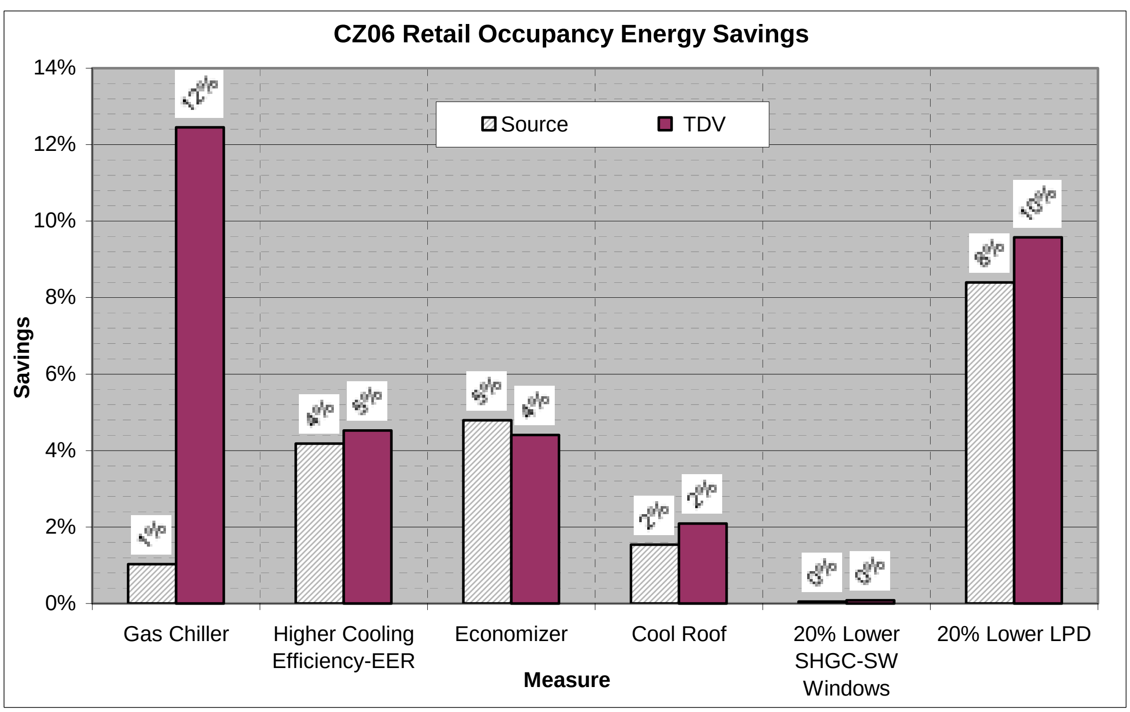

Figure E-2 - CTZ 6 Retail Parametrics

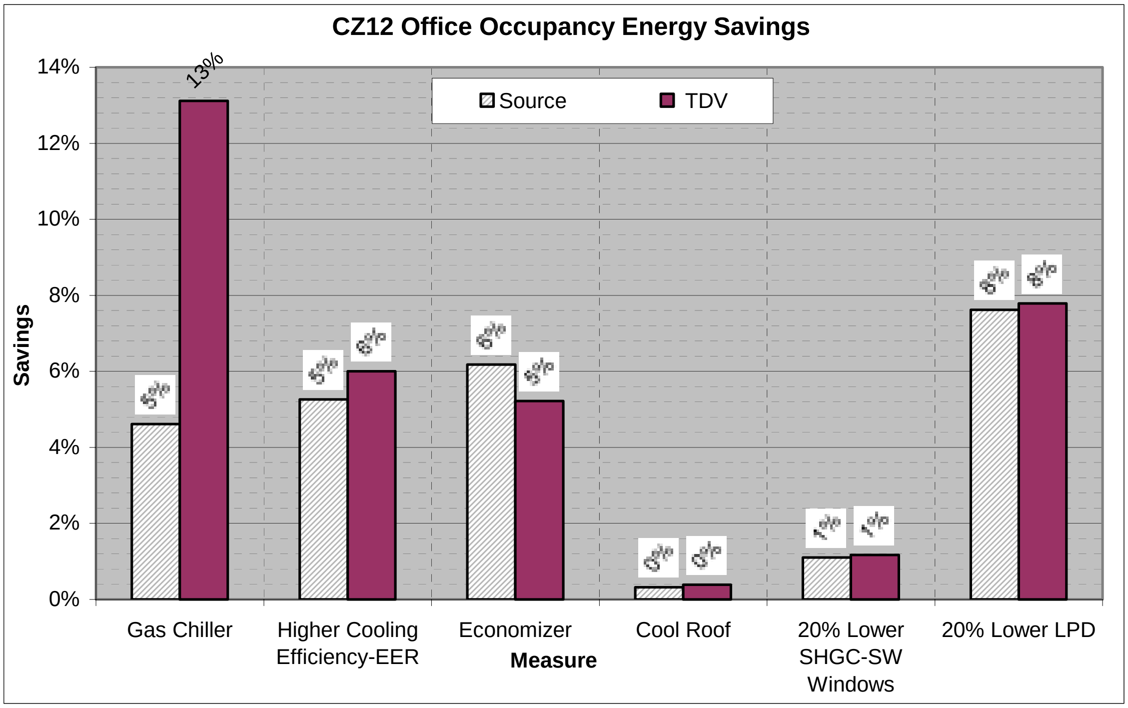

Figure E-3 - CTZ 12 Office Parametrics

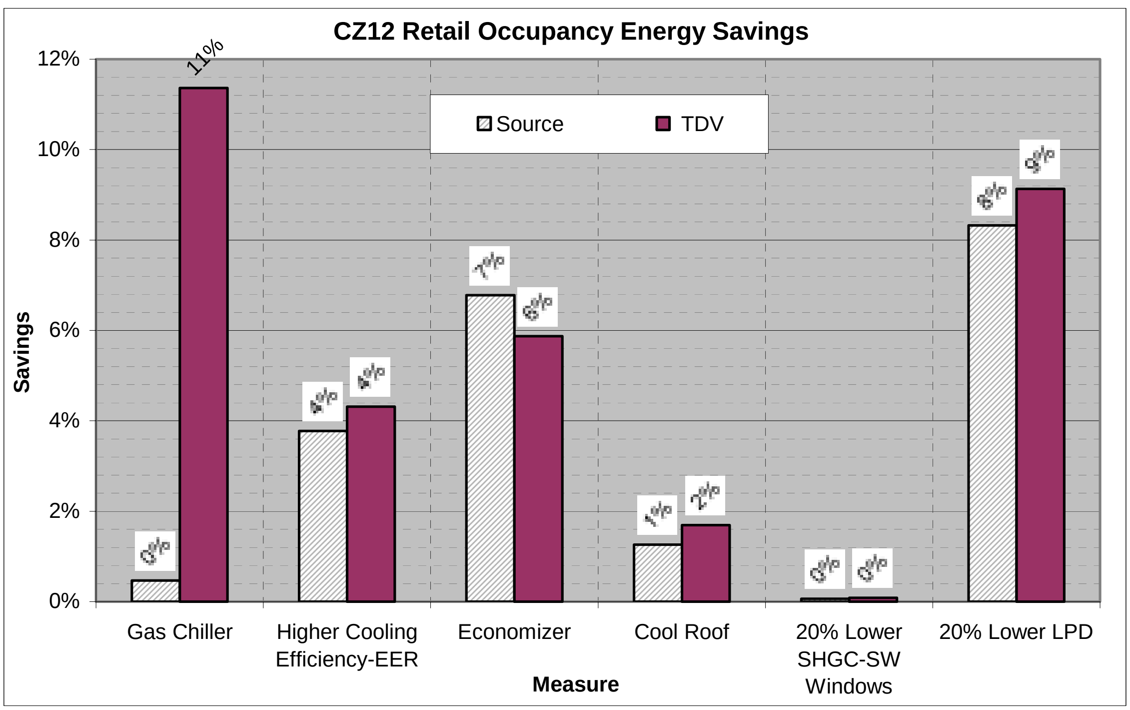

Figure E-4 - CTZ 12 Retail Parametrics

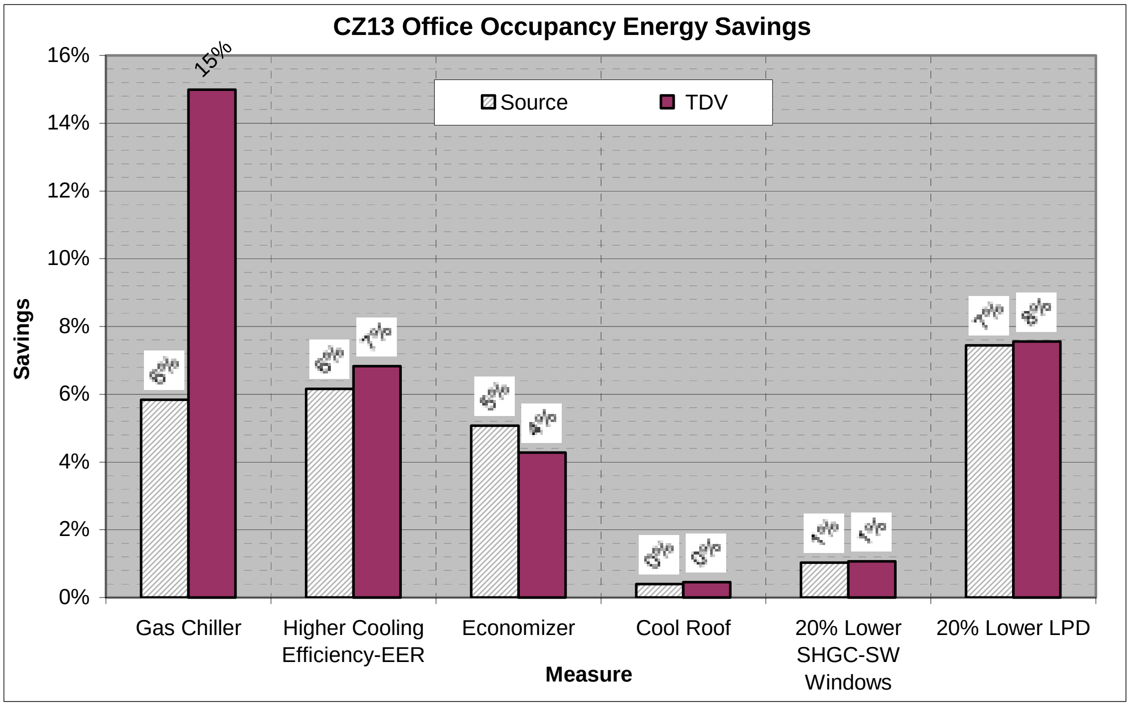

Figure E-5 - CTZ 13 Office Parametrics

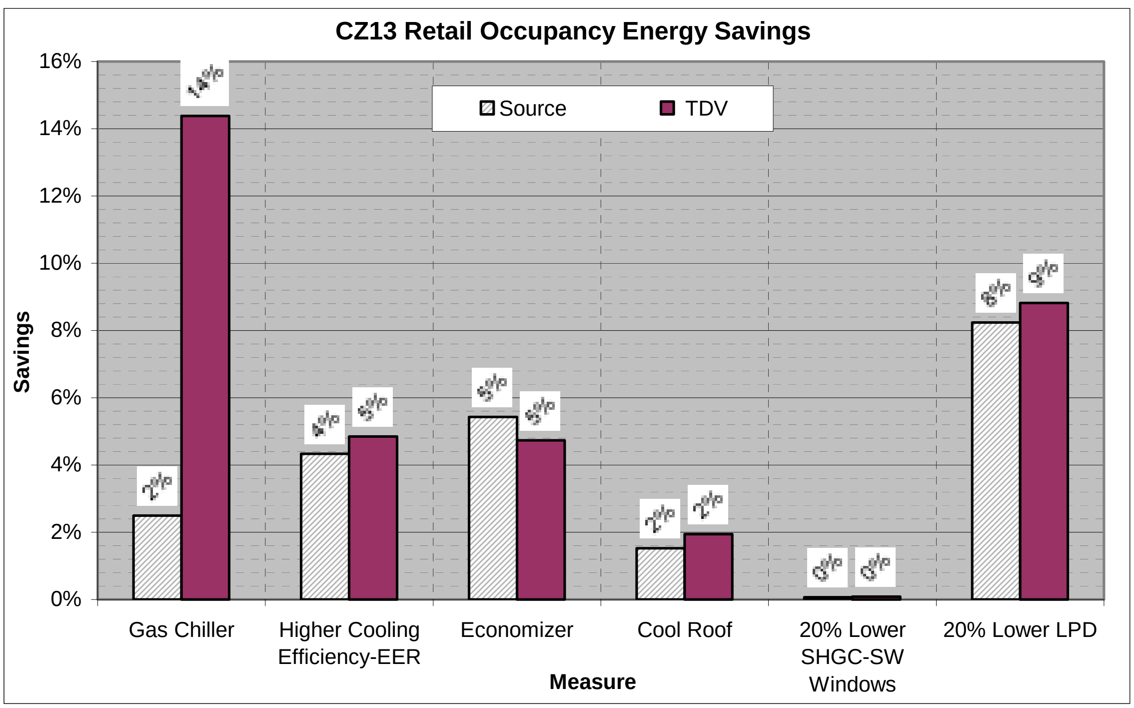

Figure E-6 - CTZ 13 Retail Parametrics

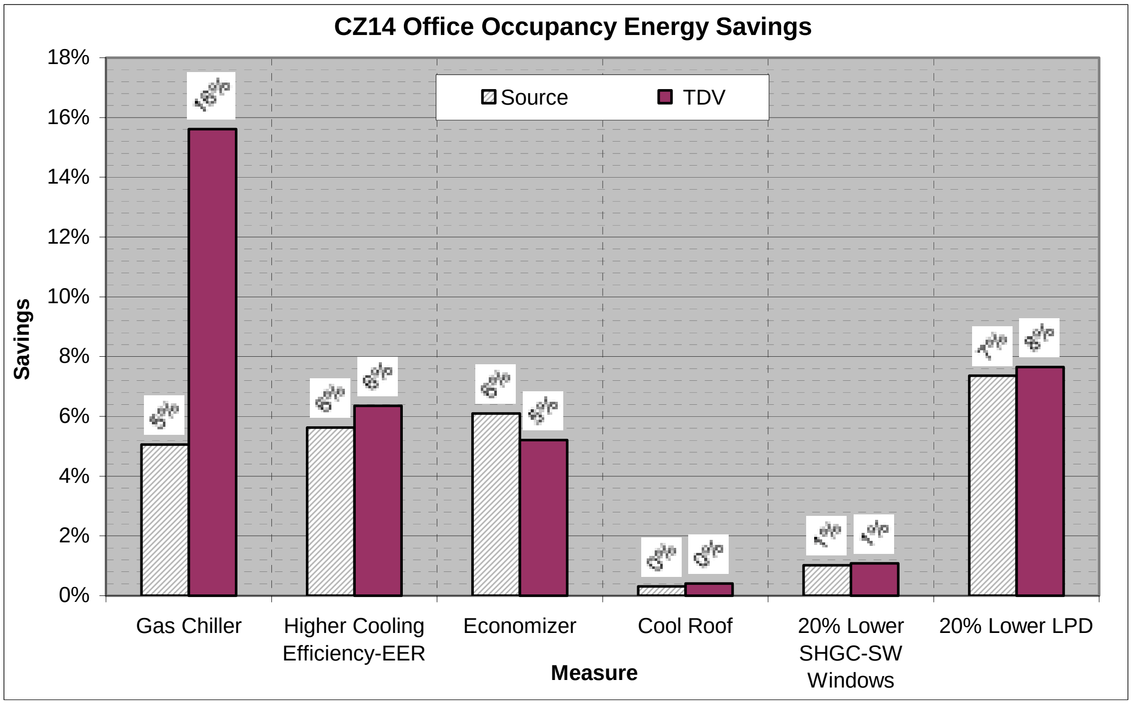

Figure E-7 - CTZ 14 Office Parametrics

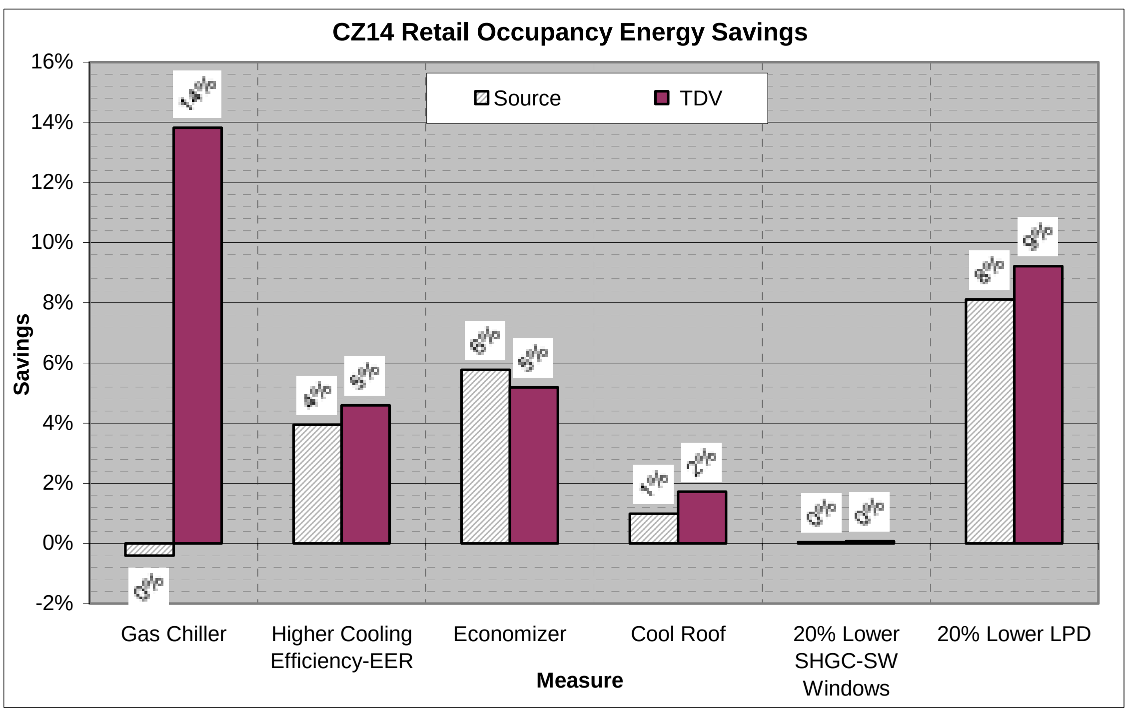

Figure E-8 - CTZ 14 Retail Parametrics

Appendix D – Excerpts from the Warren-Alquist Act

The following paragraphs are excerpted from the Warren-Alquist Act, Division 15 of the Public Resources Code, which is the legislation which enabled the Title 24 standards. The underlined sections speak to the issues of environmental externalities, and to the valuation of energy savings.

§ 25000.1. Legislative finding; energy resources cost effectiveness, value for environmental costs/benefits

(a) The Legislature further finds and declares that, in addition to their other ratepayer protection objectives, a principal goal of electric and natural gas utilities' resource planning and investment shall be to minimize the cost to society of the reliable energy services that are provided by natural gas and electricity, and to improve the environment and to encourage the diversity of energy sources through improvements in energy efficiency and development of renewable energy resources, such as wind, solar, and geothermal energy.

(b) The Legislature further finds and declares that, in addition to any appropriate investments in energy production, electrical and natural gas utilities should seek to exploit all practicable and cost-effective conservation and improvements in the efficiency of energy use and distribution that offer equivalent or better system reliability, and which are not being exploited by any other entity.

(c) In calculating the cost effectiveness of energy resources, including conservation and load management options, the commission shall include a value for any costs and benefits to the environment, including air quality. The commission shall ensure that any values it develops pursuant to this section are consistent with values developed by the Public Utilities Commission pursuant to Section 701.1 of the Public Utilities Code. However, if the commission determines that a value developed pursuant to this subdivision is not consistent with a value developed by the Public Utilities Commission pursuant to subdivision (c) of Section 701.1 of the Public Utilities Code, the commission may nonetheless use this value if, in the appropriate record of its proceedings, it states its reasons for using the value it has selected.

§ 25402. Duties of commission; hearings; standards; appliances to display date of manufacture

The commission shall, after one or more public hearings, do all of the following, in order to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy:

(a) Prescribe, by regulation, lighting, insulation climate control system, and other building design and construction standards which increase the efficiency in the use of energy for new residential and new nonresidential buildings. The standards shall be cost-effective, when taken in their entirety, and when amortized over the economic life of the structure when compared with historic practice. ....

(b) Prescribe, by regulation, energy conservation design standards for new residential and new nonresidential buildings. The standards shall be performance standards and shall be promulgated *in terms of energy consumption per gross square foot of floorspace*, but may also include devices, systems, and techniques required to conserve energy. The standards shall be cost-effective when taken in their entirety, and when amortized over the economic life of the structure when compared with historic practices. .....

Appendix E - Summary Statistics of Time Dependent Valuations

Appendix F – TDV Cookbook